Department of Engineering & Design

University of Sussex

Professor Chris Chatwin

MSc Satellite & Space Systems - Introduction & Overview

25th April 2017

Advanced Space Systems - Topics

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- Space vehicle Power Systems
- Rocketry and propulsion systems
- Orbital Mechanics
- Applications
- Security

Space Applications

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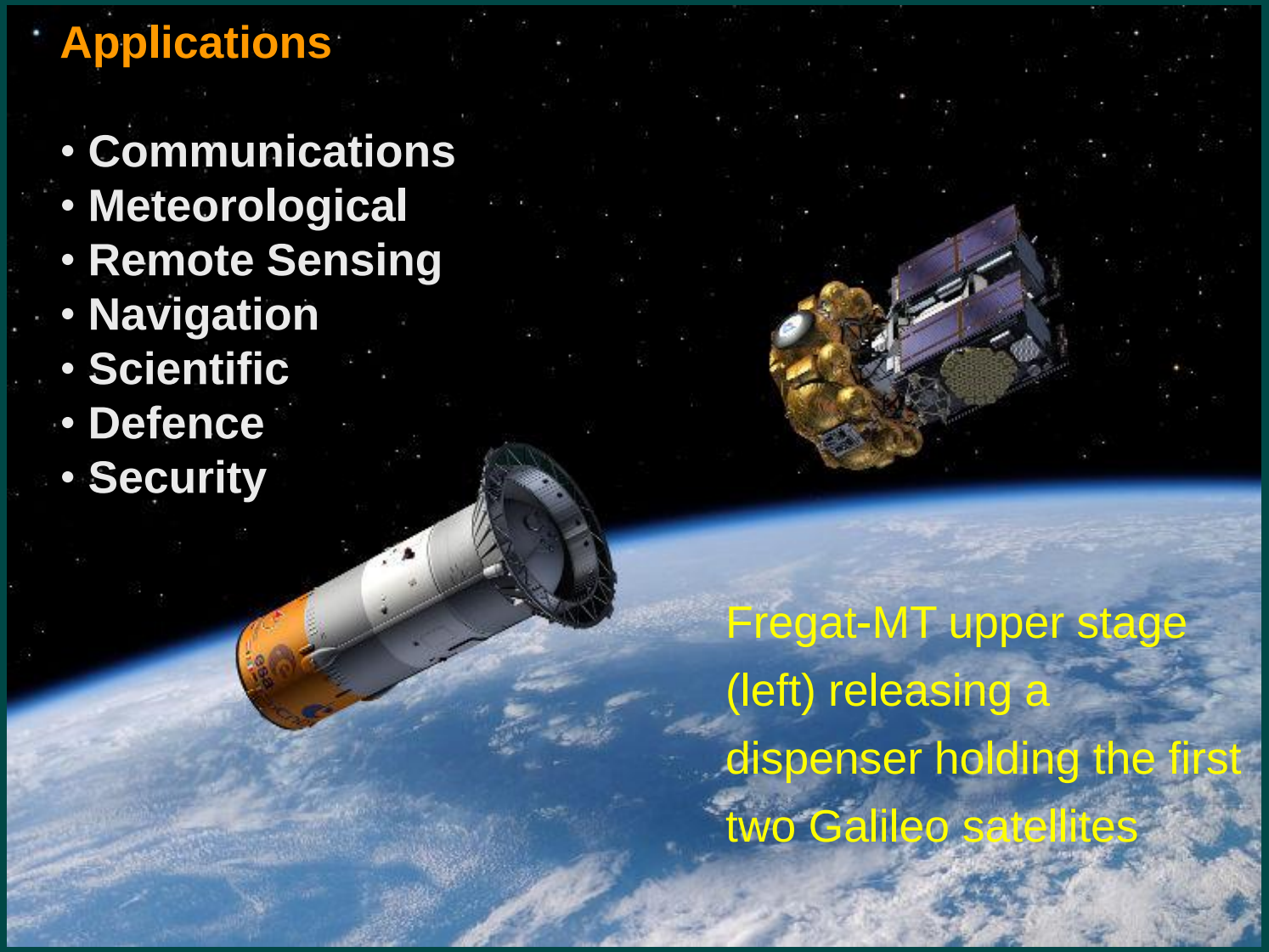

Global Positioning System

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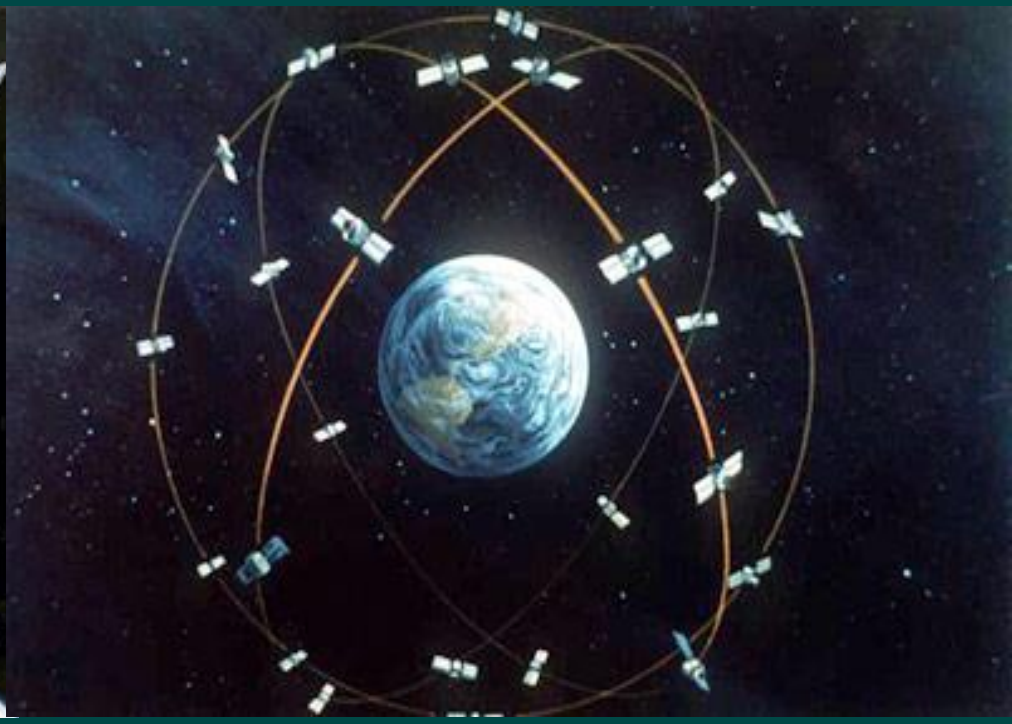

- 24 spacecraft in 12 hour circular orbits, with 3 on-orbit spares. Six circular orbital planes, R=26,560km
- All users with clear view of sky see the minimum of 4, but usually see 6-8
- Augmentation generally not only improves accuracy but integrity, availability and continuity of GPS signals and GNSS signals generally.

EADS Astrium Ka-SAT, 6.1 Tonnes at launch, 15 year lifetime, 11 kW

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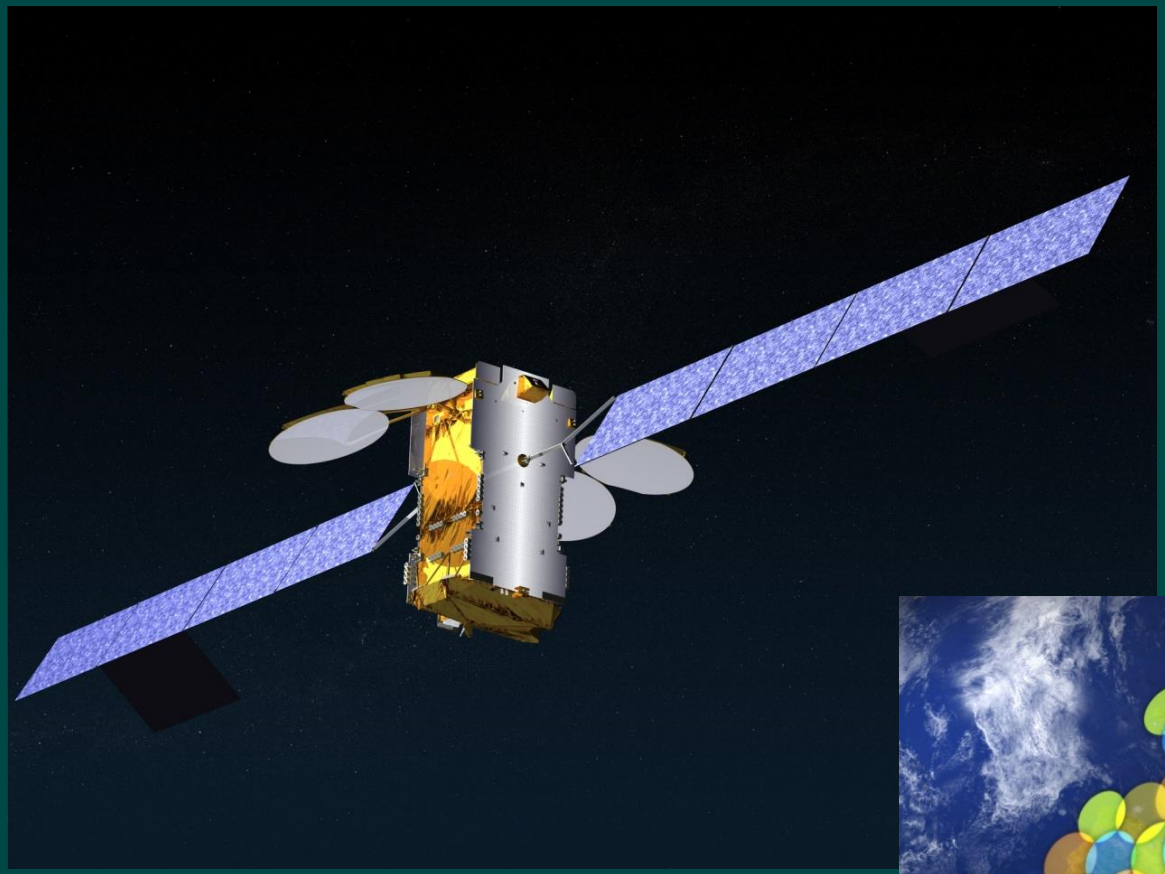
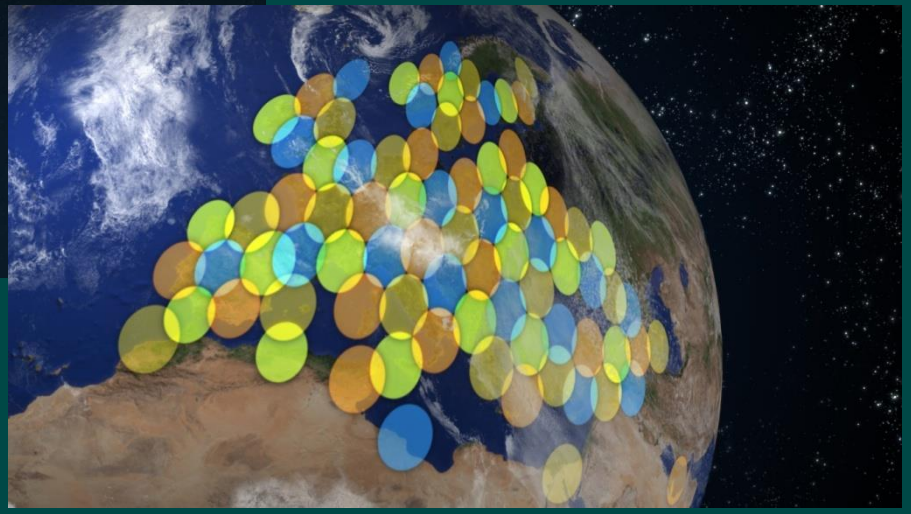


KA-SAT will provide ubiquitous complete coverage of Europe and the Mediterranean Basin through its 82 spot beams in Ka-band



Global Positioning System

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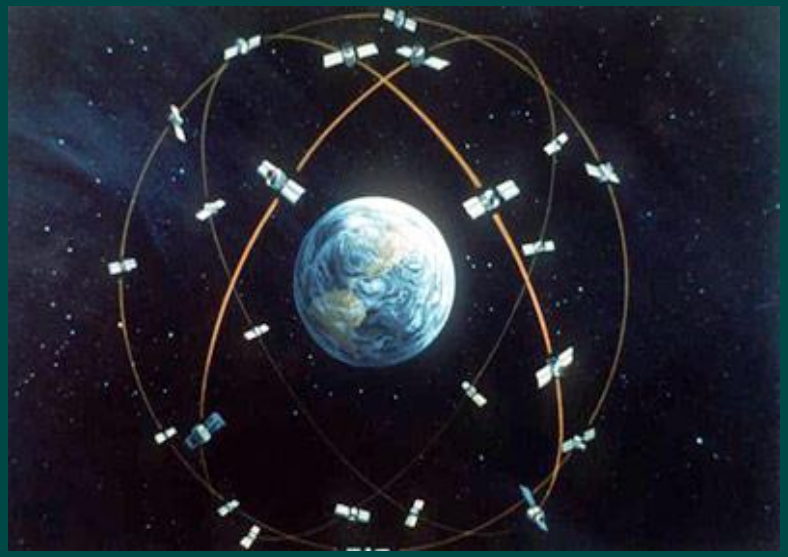

24 spacecraft in 12 hour circular orbits, with 3 on-orbit spares. Six circular orbital planes, R=26,560km

GPS User: Horseback Biologist in Amazon

Virtual Private Networks over Satellite

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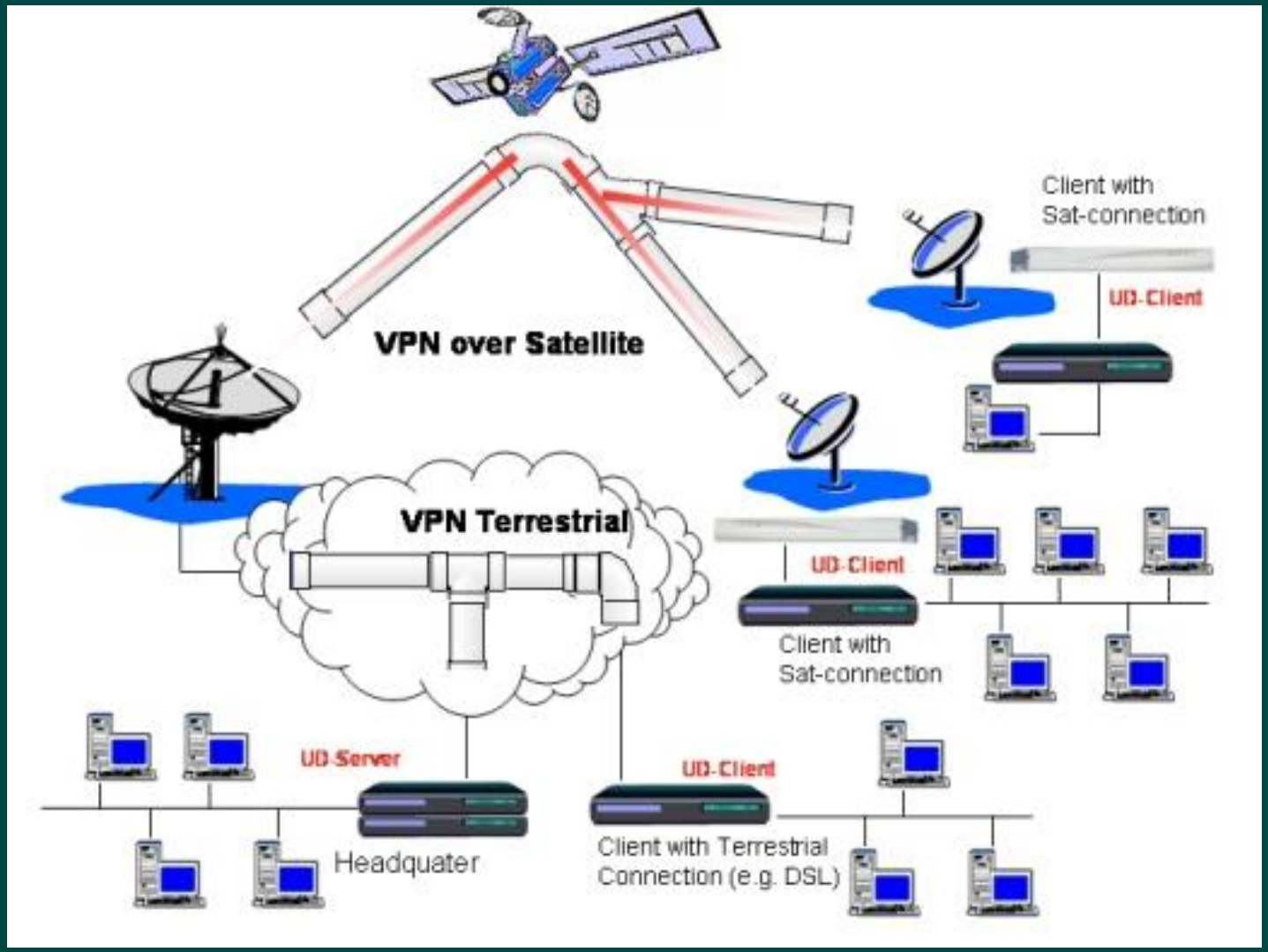

Untethered Trailer Tracking Wireless Terrestrial Communications

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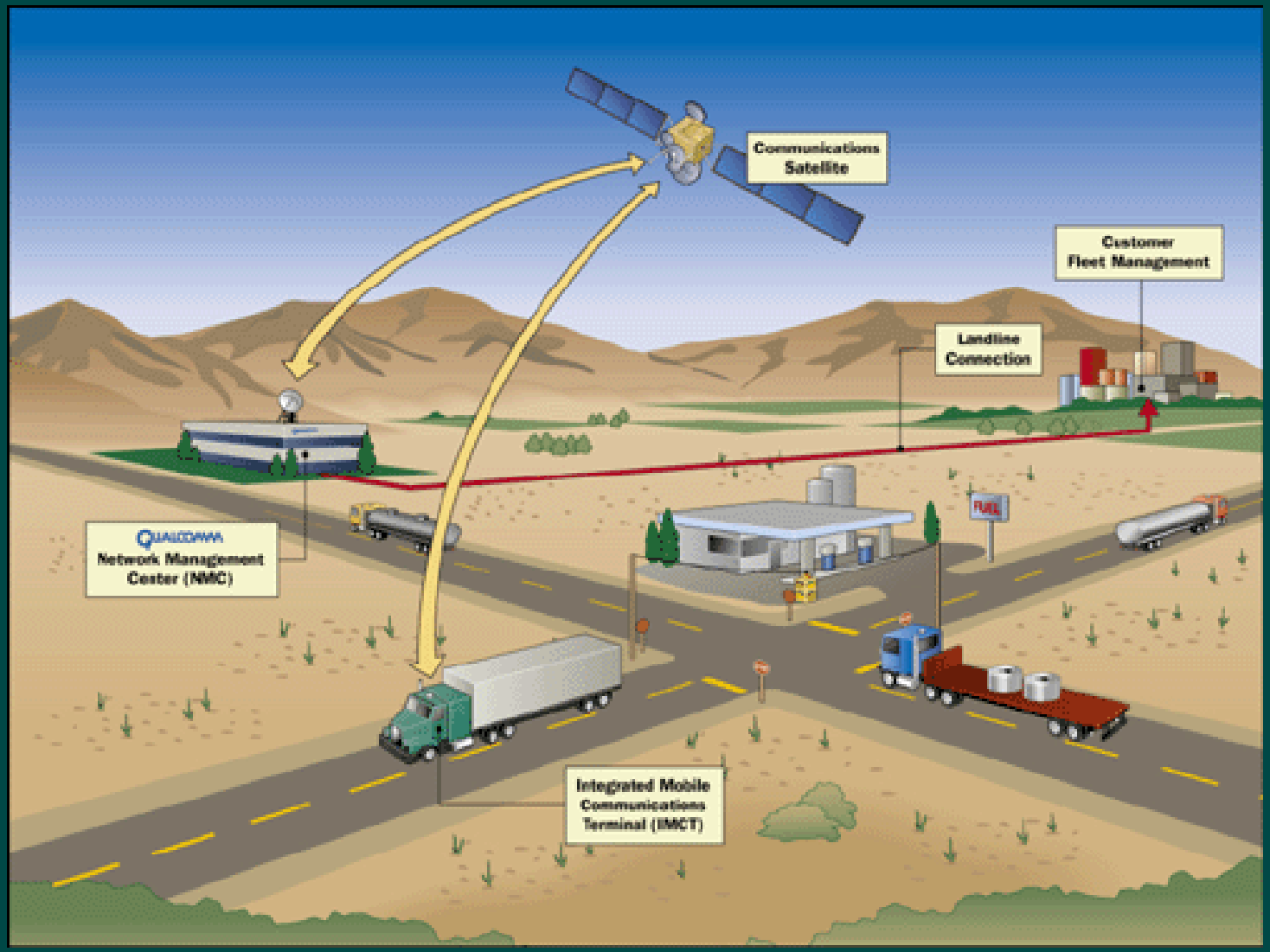

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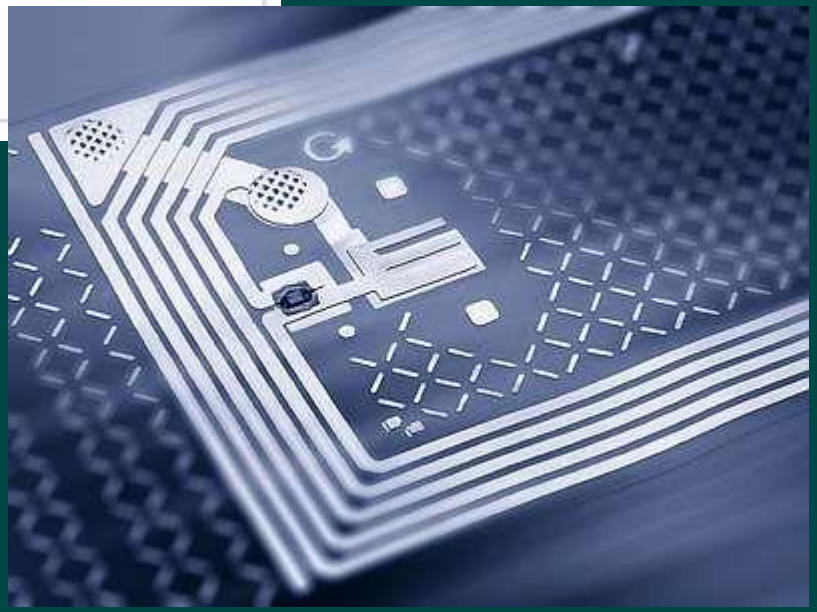
RFID



Galileo should be operation by 2017, it will be inter-operable with GPS and GLONASS

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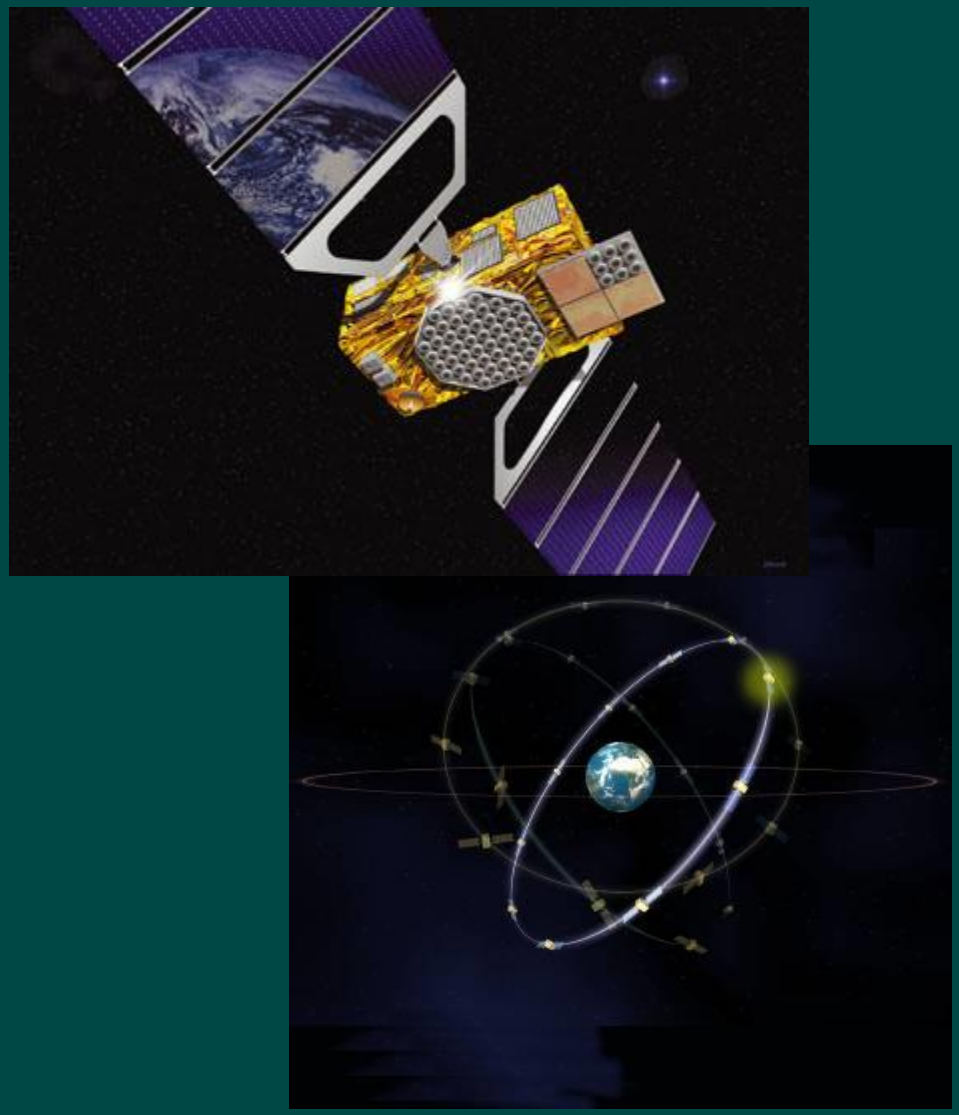

30 satellites in Medium Earth Orbit (MEO) at an altitude of 23 222 km

Ten satellites will occupy each of three orbital planes inclined at an angle of 56° to the equator.

The inclination of the orbits was chosen to ensure good coverage of polar latitudes, which are poorly served by the US GPS system.

NASA Satellites

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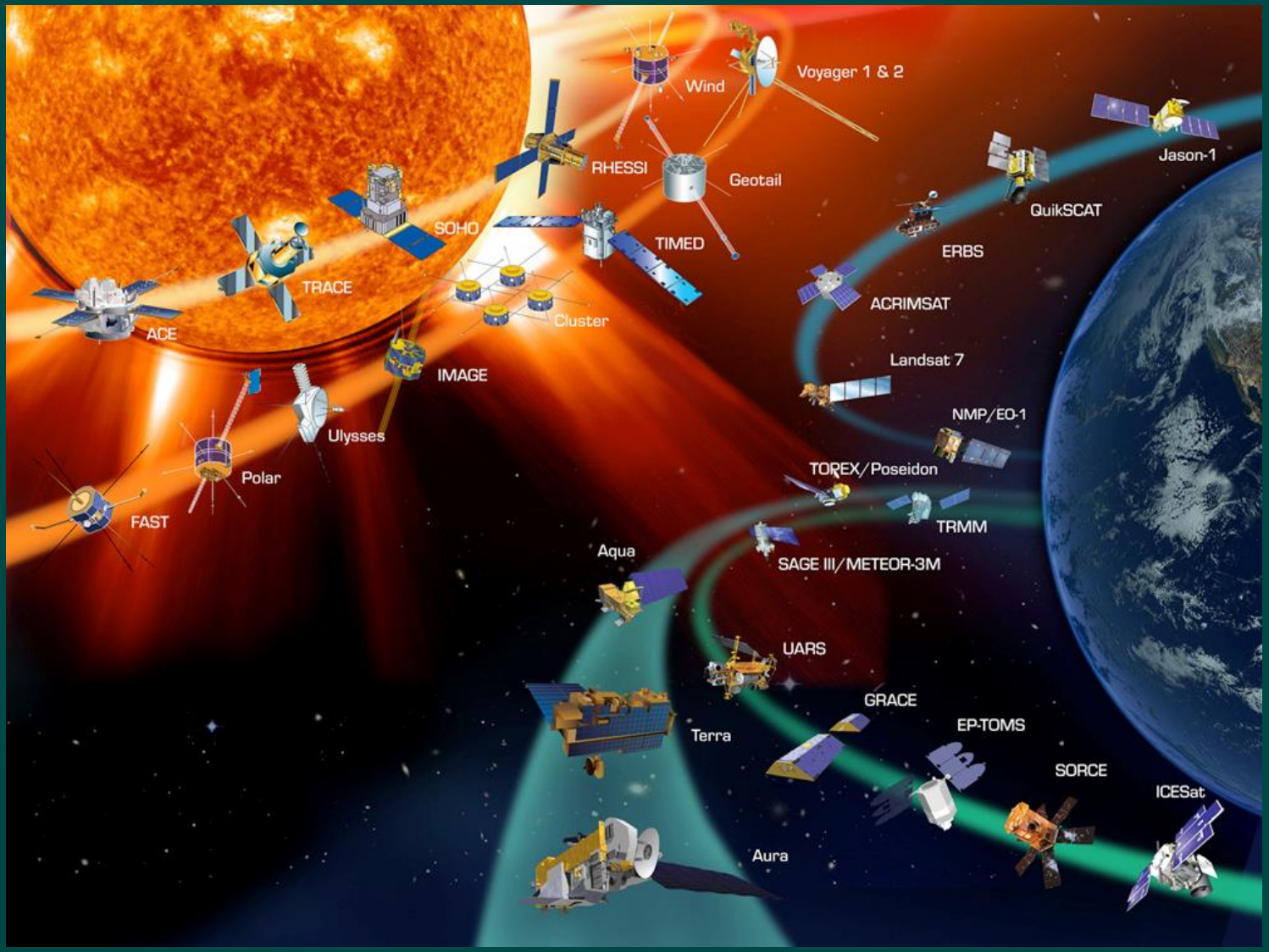

Space Surveillance Network

Worldwide Network of 20 Optical and Radar (Mechanical & Phased Array) Sensor Sites

Ground-*Based* Electro-Optical Deep *Space* Surveillance (GEODSS) - Diego Garcia / Maui / Socorro

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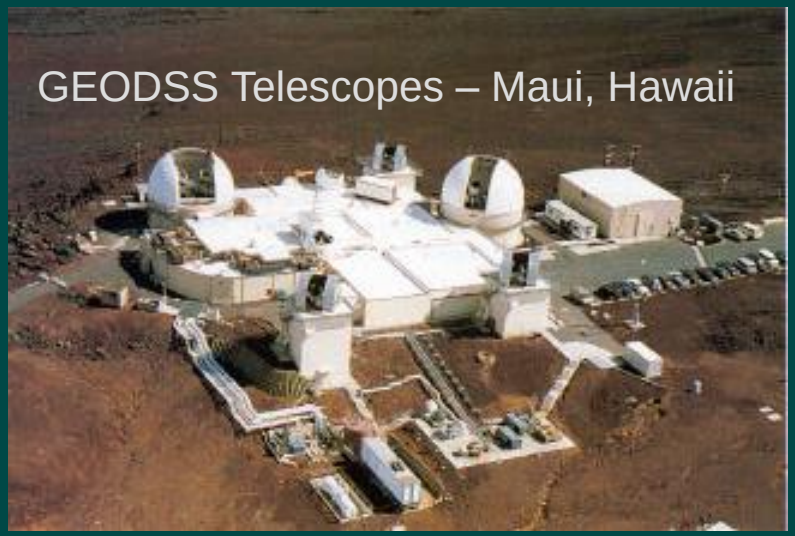
- Primary Mission: Space Surveillance
- Supports Air Force Space Command (AFSPC) as a dedicated Deep Space (DS) sensor
- GEODSS brings together the telescope, low-light-level cameras, and computers



Inside Diego Garcia GEODSS Station

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SBSS satellite programme

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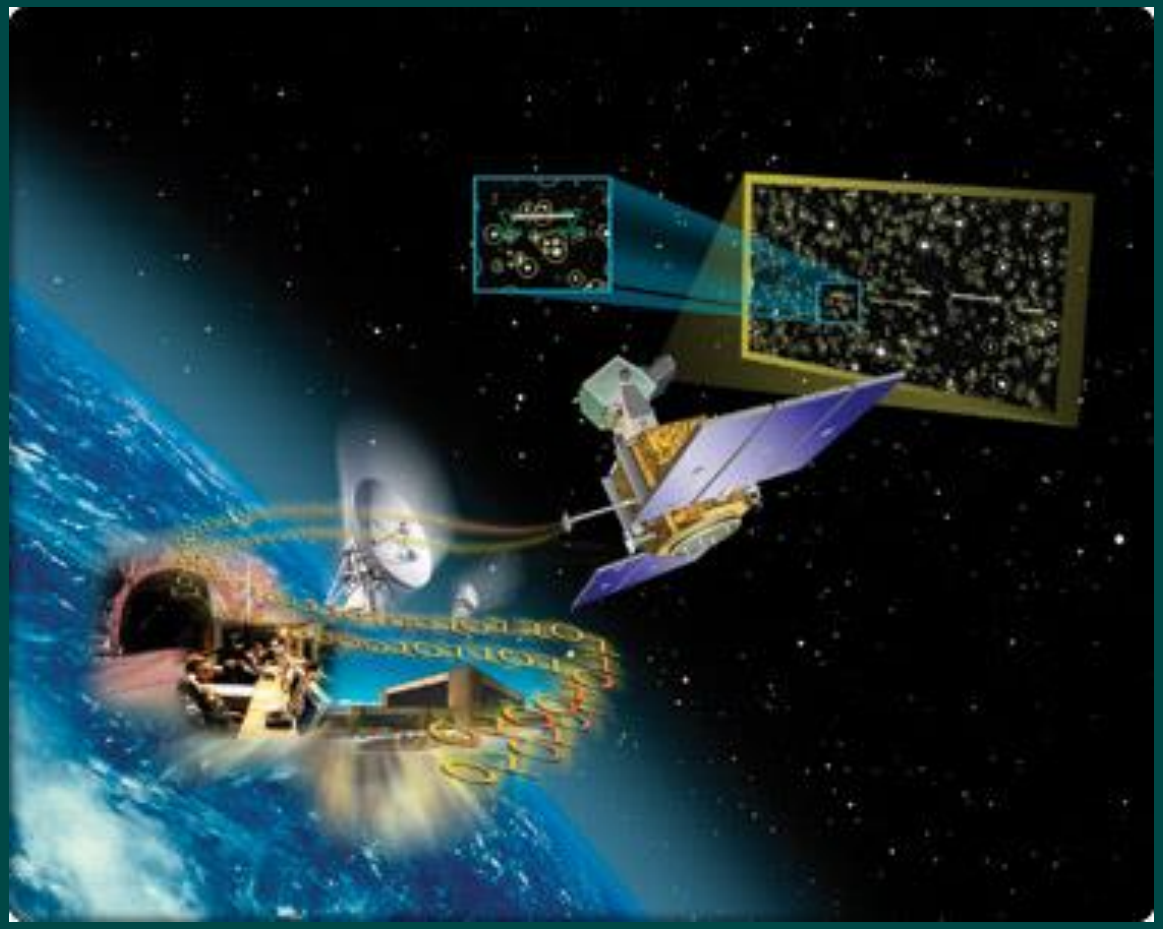

Boeing is working on the Space-Based Surveillance System (SBSS) satellite program

Space Based Space Surveillance (SBSS) - Operates in conjunction with the Space Surveillance Network (SSN)

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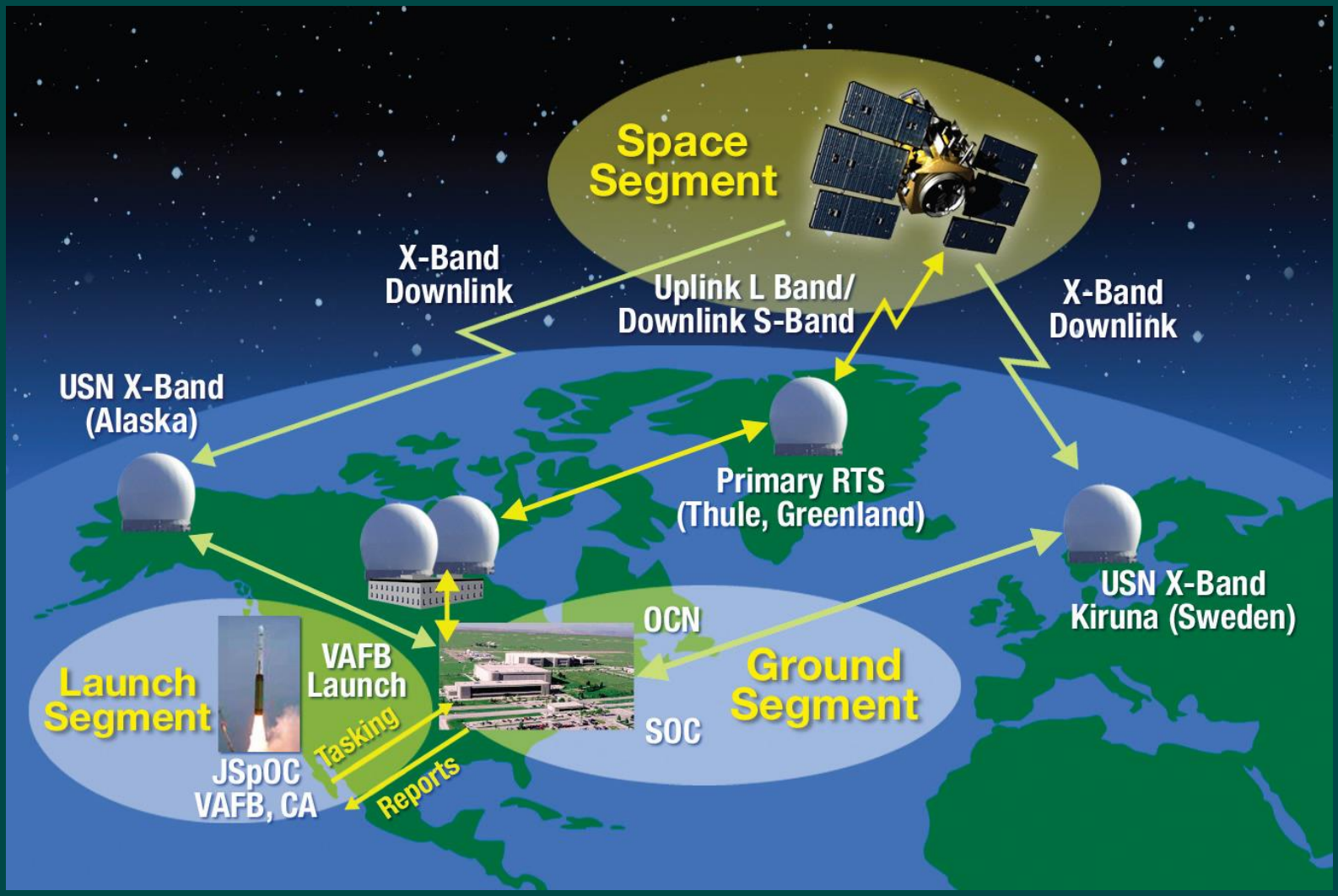

USN Universal Space Network; RTS Remote Tracking Station; VAFB Vandenberg Air Force Base;JSpOC Joint Space Operations Centre; OCN Operational Control Node; SOC Satellite Operations Center

Space Based Space Surveillance, LEO

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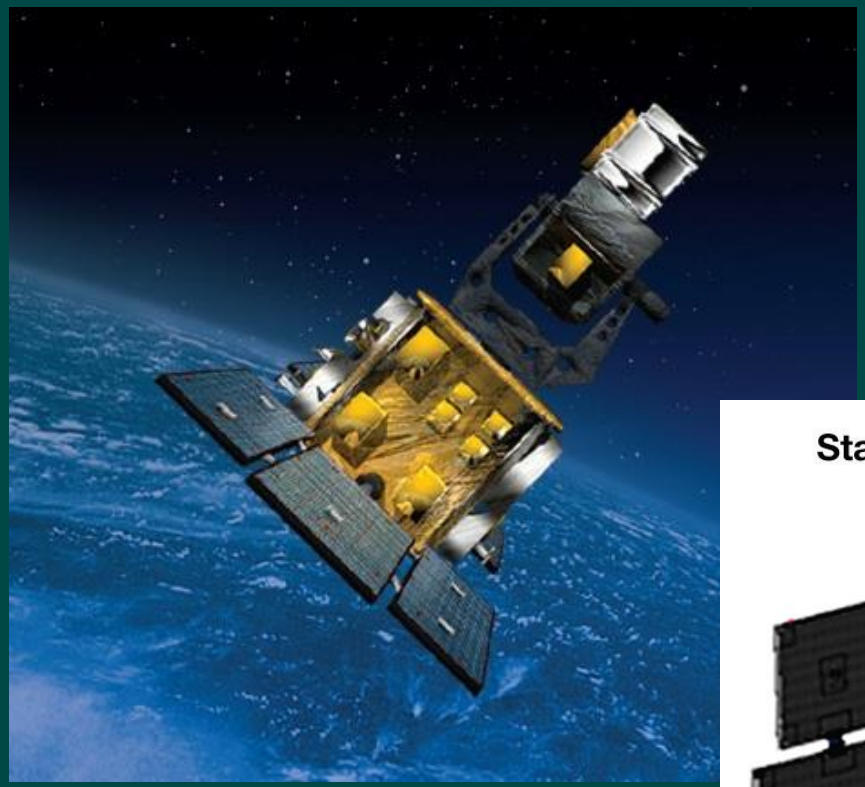
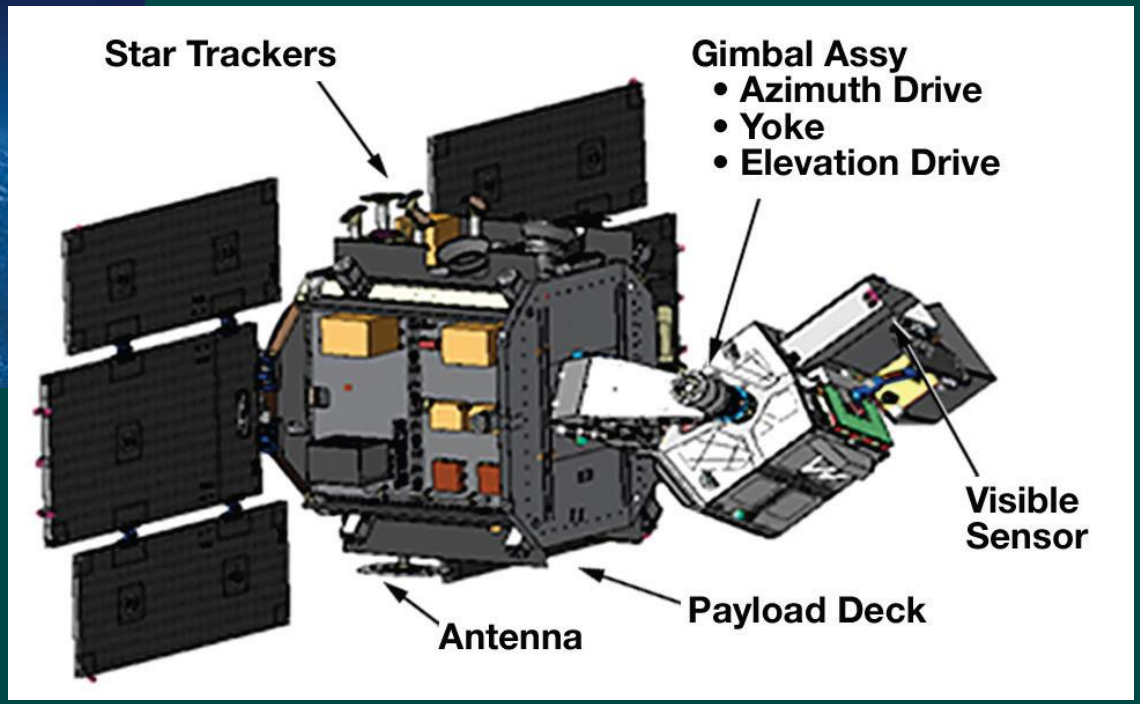


SBSS Delivers:

- 2-axis gimbaled sensor
- Large aperture
- 630-km, ~sun-sync
- 24-hr/day duty cycle



Better Timeliness

Better Sensitivity

Increased Capacity

Increased Orbit Accuracy

SBSS is free of terrestrial limitations – 24/7 on orbit data collection

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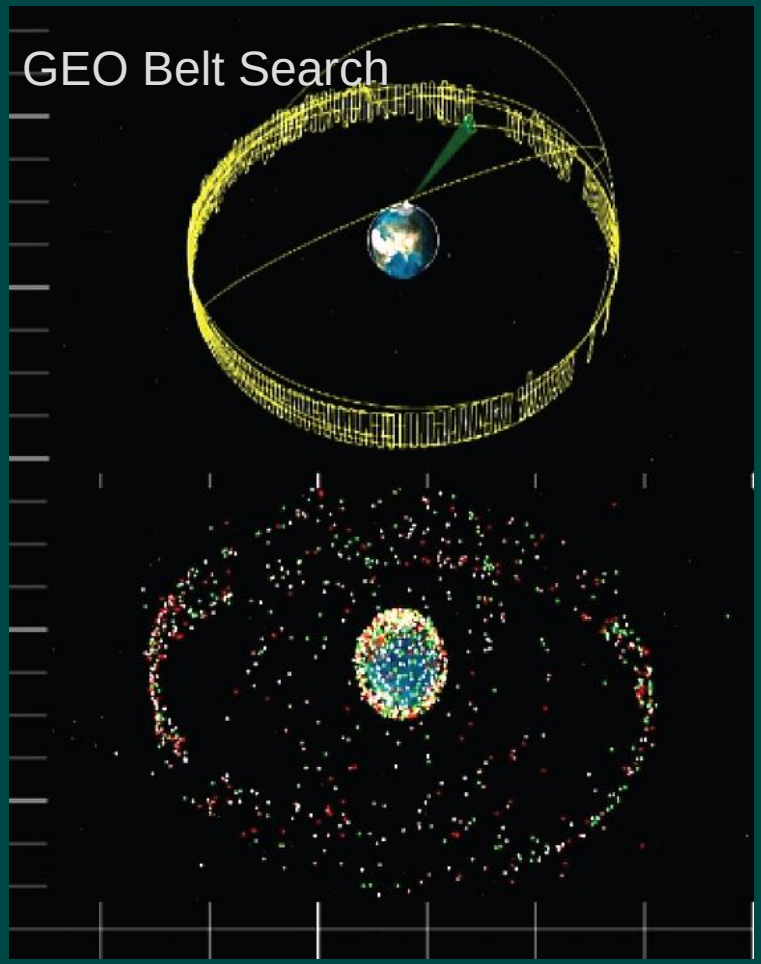
Detection of faint objects including space debris



Space Based Infrared Systems (SBIRS)

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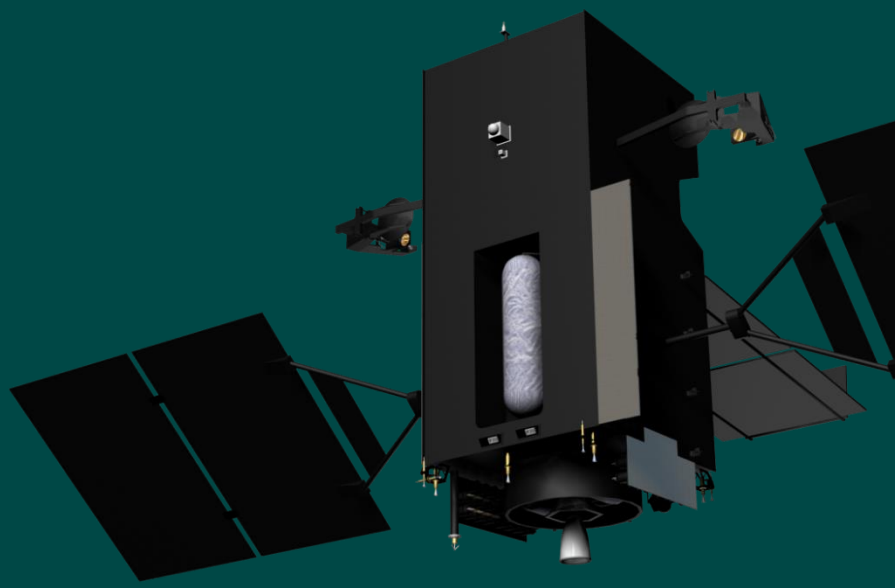

Space Based Infrared Systems (SBIRS) contributes to the Department of Defense mission to deter war and protect the security of the U.S. by providing timely and accurate missile warning/defense information. The SBIRS systems are critical for protection against global and theater ballistic missile attacks against the U.S., its deployed forces and its allies.

Defense Meteorological Satellite Program (DMSP)

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Defense Meteorological Satellite Program (DMSP) satellites "see" such environmental features as clouds, bodies of water, snow, fire, and pollution in the visual and infrared spectra. Scanning radiometers record information which can help determine cloud type and height, land and surface water temperatures, water currents, ocean surface features, ice, and snow. Communicated to ground-based terminals, the data is processed, interpreted by meteorologists, and ultimately used in planning and conducting U.S. military operations worldwide.

The NASA A-Train

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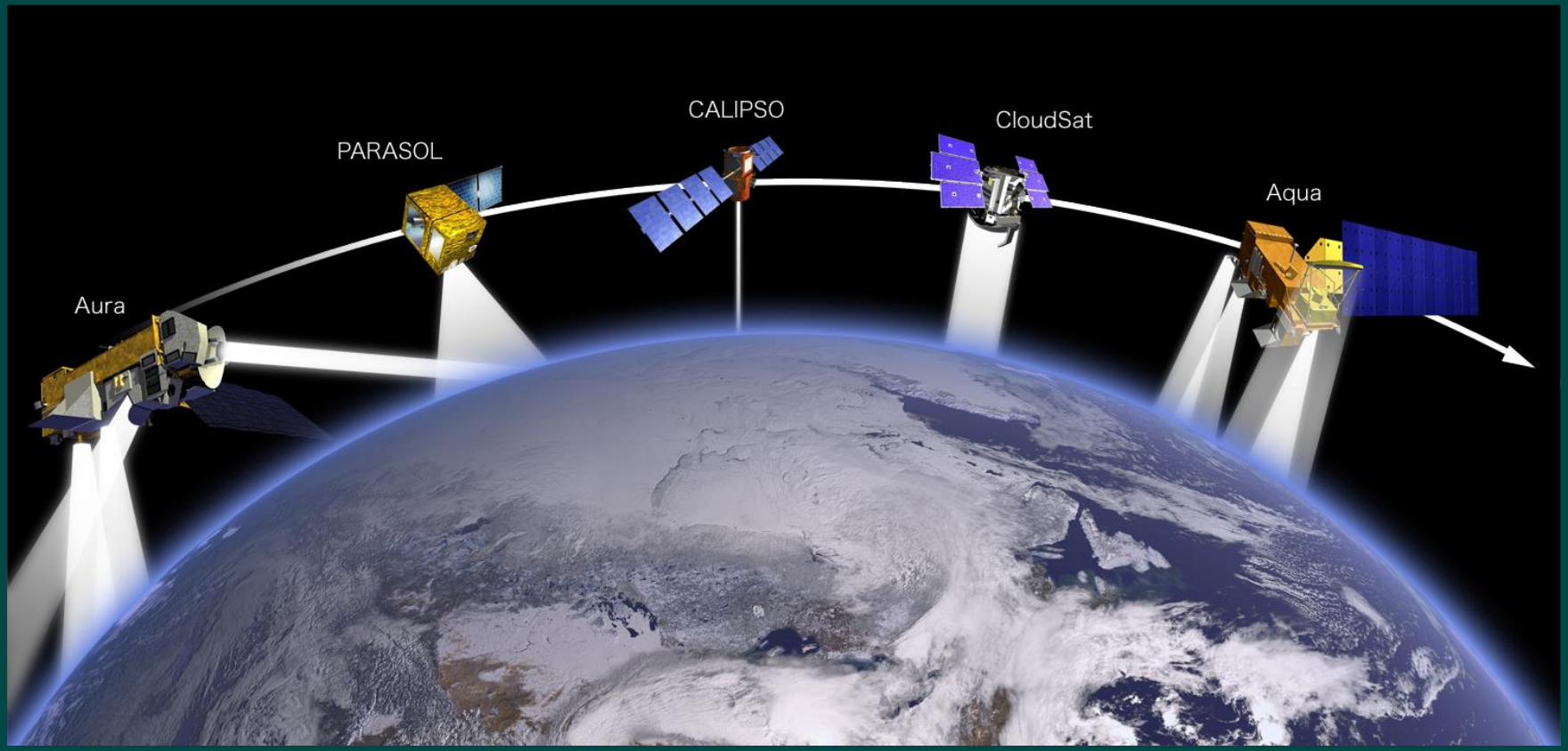

CALIPSO and CloudSat fly in formation with other Earth Observing Satellites

WGS satellite communications

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The Wideband Global SATCOM satellite is the successor to the Defence Satellite Communications System-III. One WGS satellite has about 12 times the bandwidth of a DSCS-III satellite.

Space Surveillance

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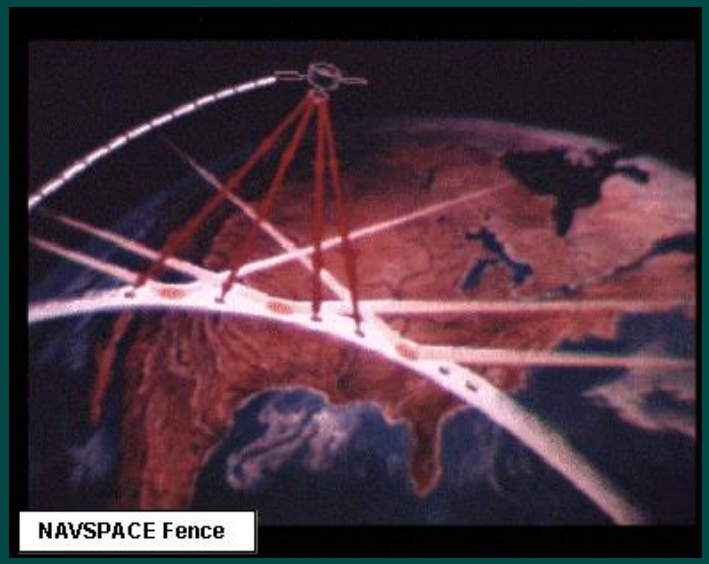
- Conduct space surveillance from space
- Surveillance of entire geosynchronous belt
- Assured access to objects of military interest



NAVSPACE Fence

- Provides up to date satellite orbital elements to Fleet and Fleet Marine forces
- Supports US Space Command as part of nation's worldwide Space Surveillance Network

Ubiquitous Sonar Surveillance Systems

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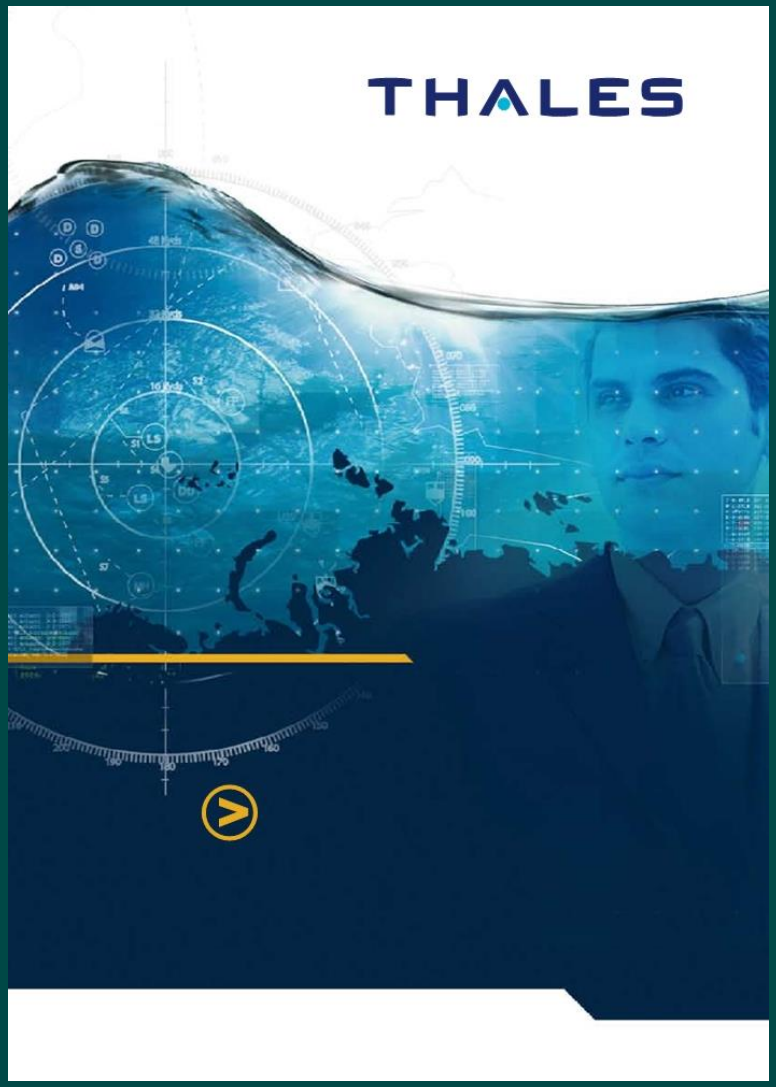

Satellite Image of Military Vehicles

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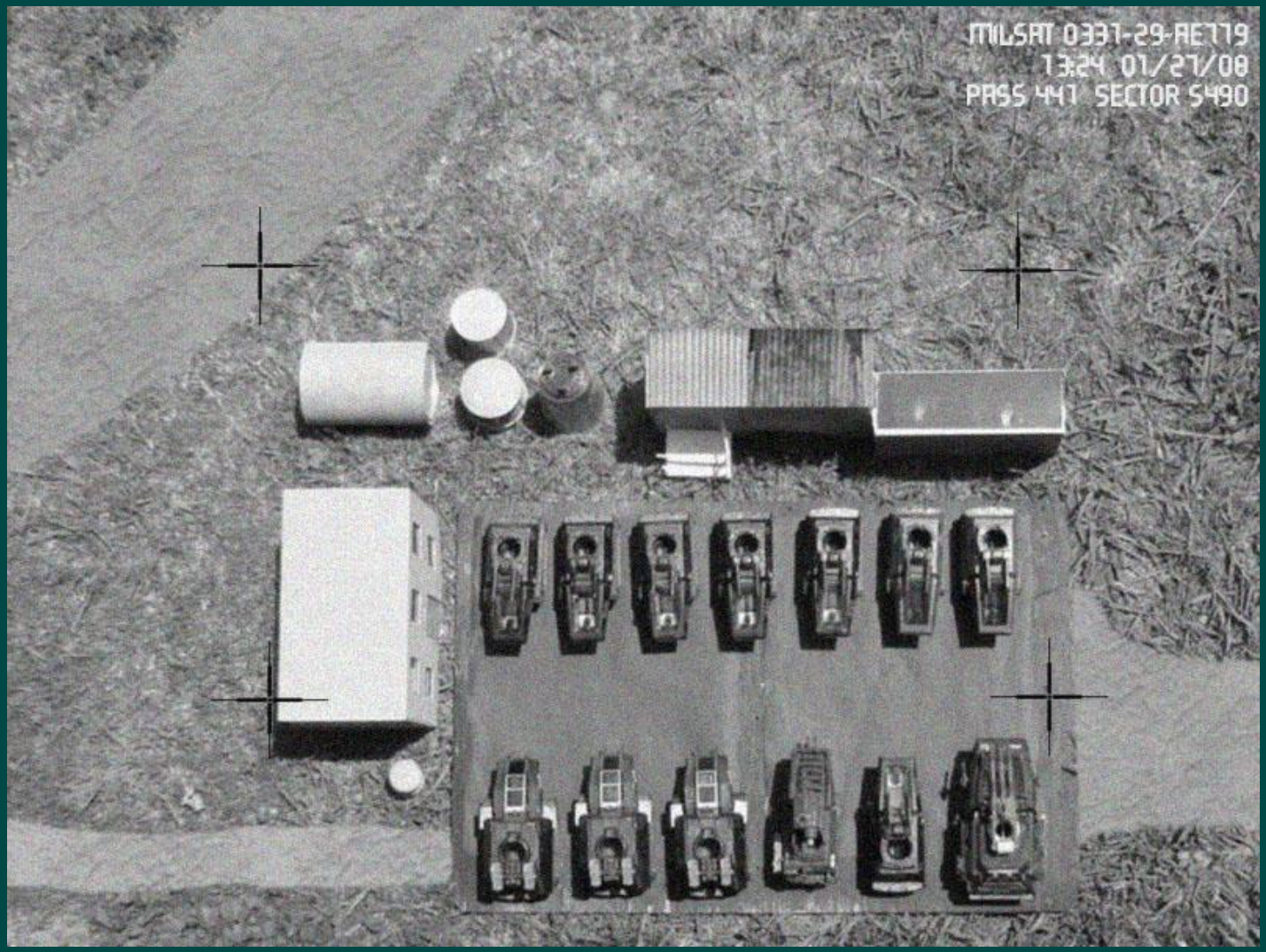

What resolution is needed

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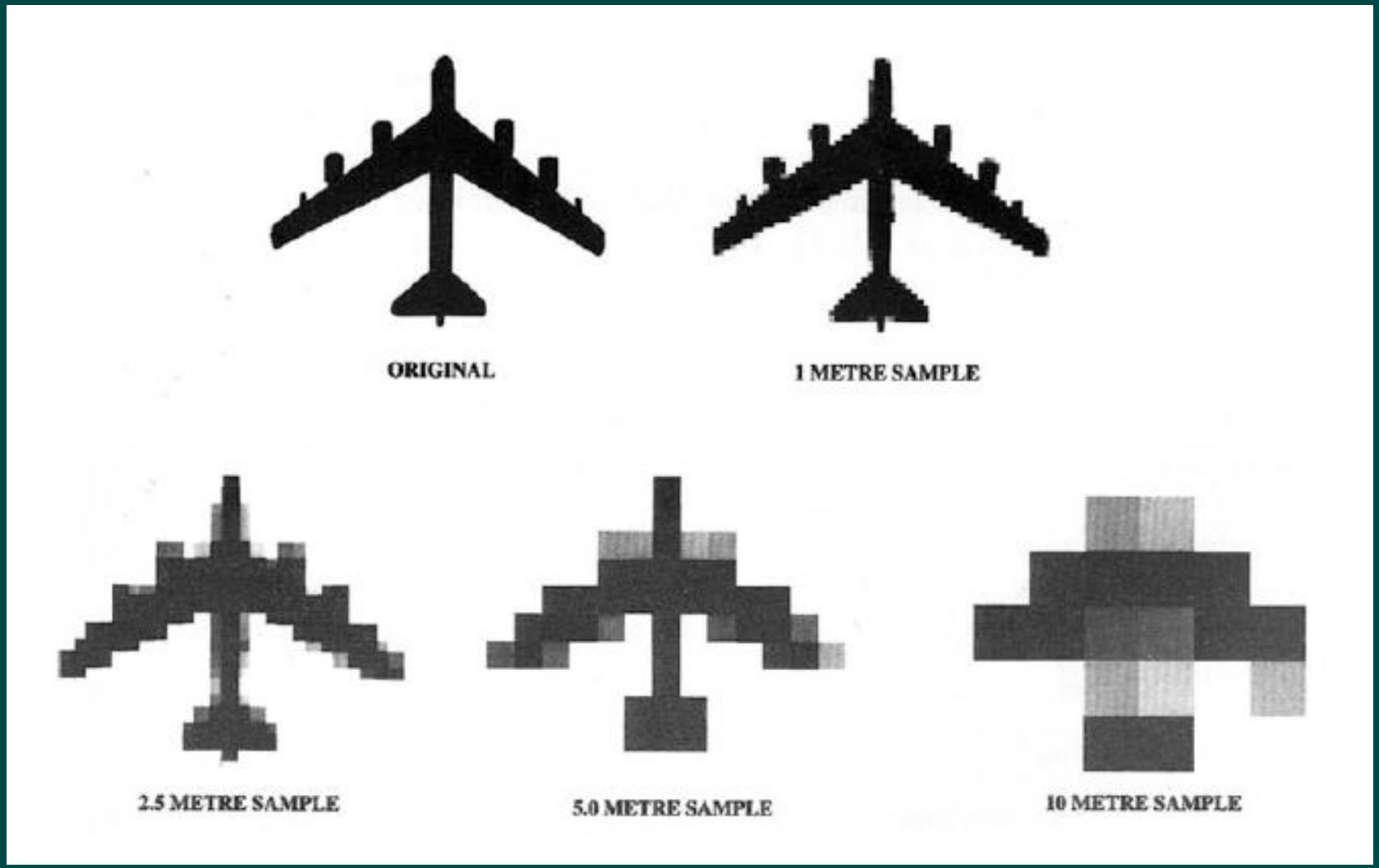

Source: B. Jasani and G. Stein, *Commercial Satellite Imagery. A Tactic in Nuclear Weapon Deterrence*, Springer, 2002

Some Sonar Systems

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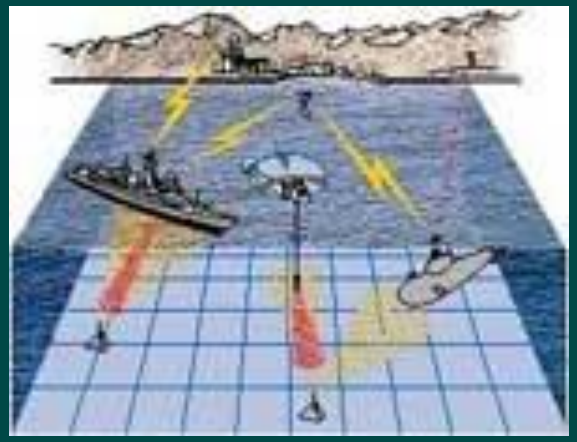

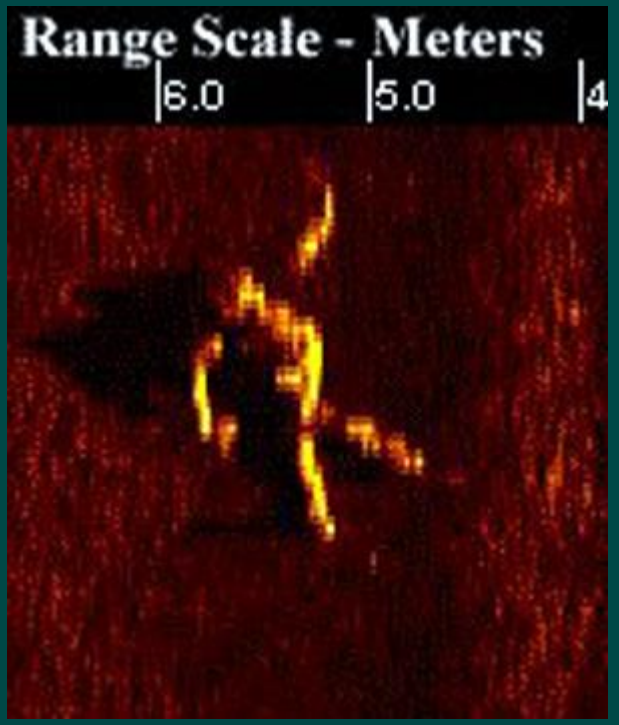

MST’s sonar systems are able to accurately identify small submerged objects such as discarded evidence or corpses, making it ideal for law enforcement investigations

Sonar Systems

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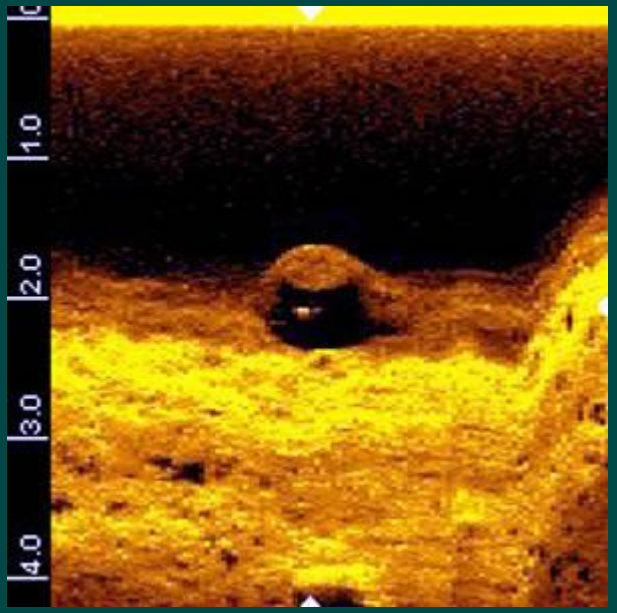
Thales CAPTAS - Combined Active / Passive Towed Array Sonar - is a family of low frequency variable depth ASW sonars for surface ships



MST's sonar detection systems can accurately image small underwater threats such as mines.

Predator - Unmanned Aerial Vehicle (UAV)

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UHF and VHF radio relay links, a C-band line-of-sight data link which has a range of 150nm and UHF and Ku-band satellite data links.

The vehicle carries electro-optical and infrared cameras and a synthetic aperture radar.

The two-colour DLTV television is equipped with a variable zoom and 955mm Spotter. The high resolution FLIR has six fields of view, 19mm to 560mm.

Global Hawk High-Altitude, Long-Endurance, Unmanned Reconnaissance Aircraft, USA

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Performance:

Maximum Endurance: 42 hours

Loiter Velocity = 343kt

Maximum Altitude: 65,000ft

Communications:

Satellite Comms Datalink

1.5Mbps, 8.67Mbps, 20Mbps, 30Mbps, 40Mbps, 47.9Mbps

Line of Sight (LOS) Datalink

137Mbps

Synthetic Aperture Radar (SAR) - 1m/0.3m resolution (WAS / Spot)

Moving Target Indicator - 4kt minimum detectable velocity

Electro-Optical - NIIRS 5.5 / 6.5 (WAS/Spot)

Infrared - NIIRS 5.0 / 6.0 (WAS/Spot)

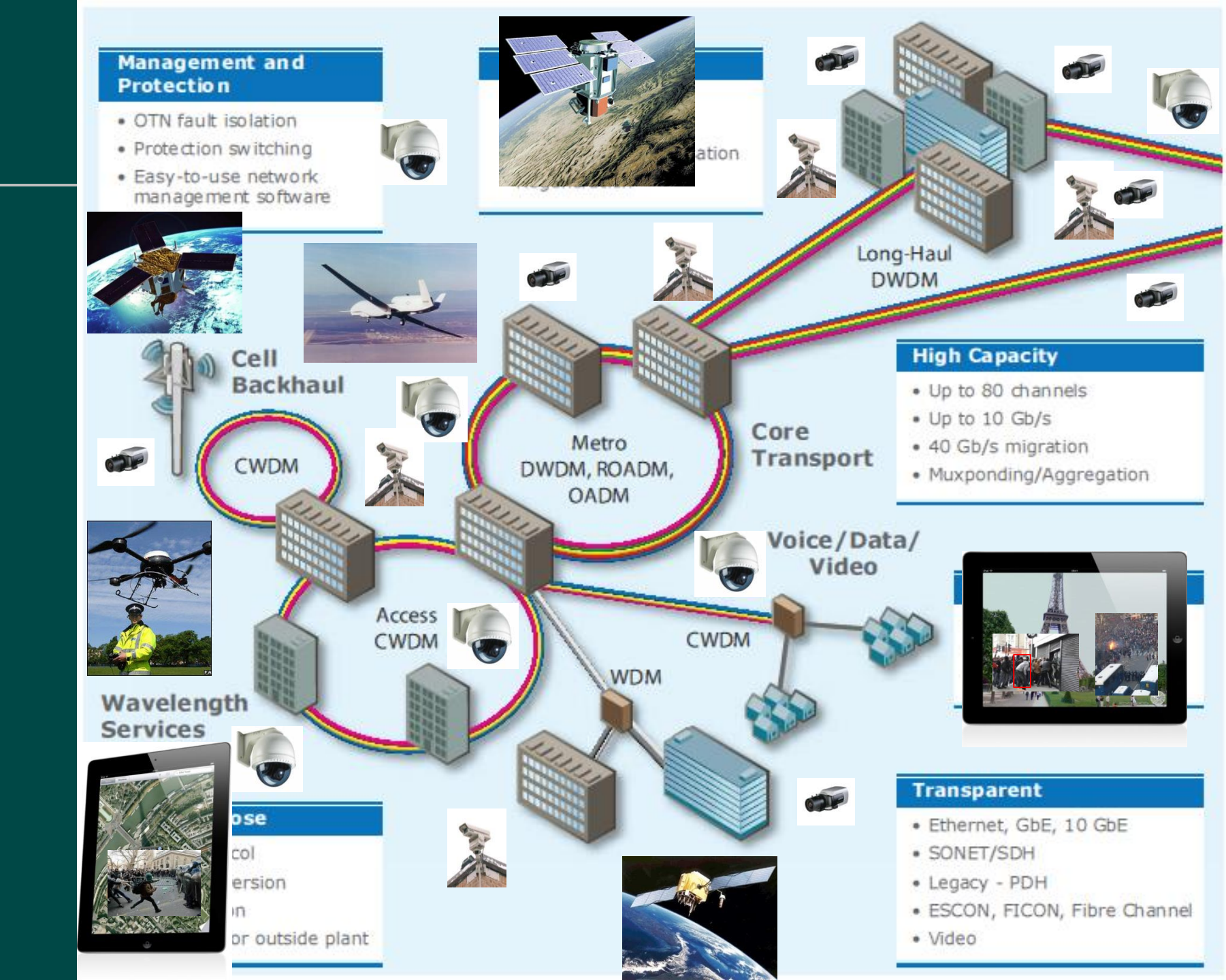
Management and Protection
• OTN fault isolation
• Protection switching
• Easy-to-use network management software
Long-Haul DWDM
Cell Backhaul
CWDM
Metro DWDM, ROADM, OADM
Core Transport
High Capacity
• Up to 80 channels
• Up to 10 Gb/s
• 40 Gb/s migration
• Muxponding/Aggregation
Voice/Data/ Video
Access CWDM
CWDM
WDM
Wavelength Services
Transparent
• Ethernet, GbE, 10 GbE
• SONET/SDH
• Legacy - PDH
• ESCON, FICON, Fibre Channel
• Video

Diagram of Total Information Awareness system, taken from official (decommissioned) Information Awareness Office website

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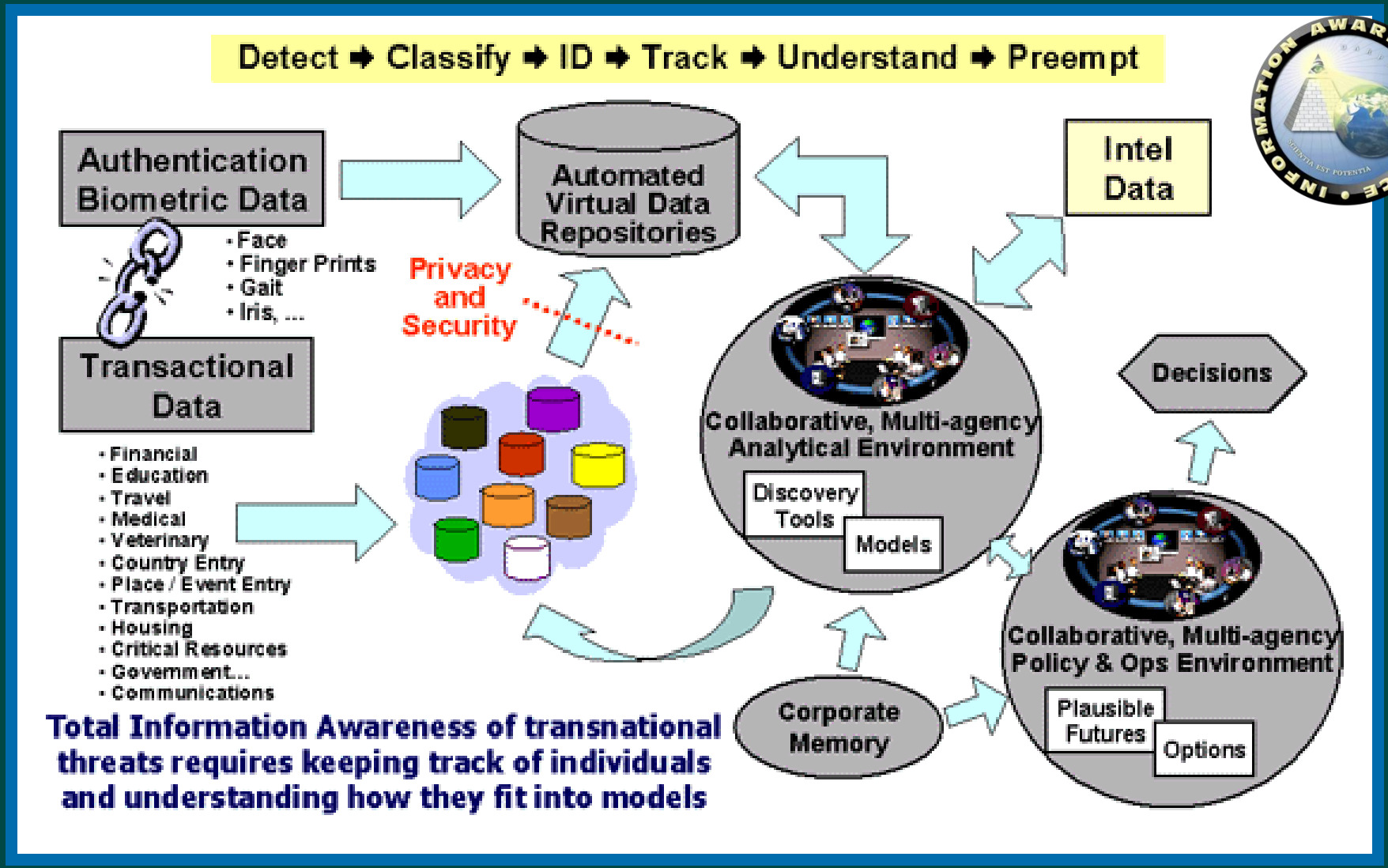

Police UAV

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Police in the Liverpool region made Britain's first ever arrest using a camera mounted on a remote control eye-in-the-sky mini-helicopter.

EADS Astrium Ka-SAT, 6.1 Tonnes at launch, 15 year lifetime, 11 kW

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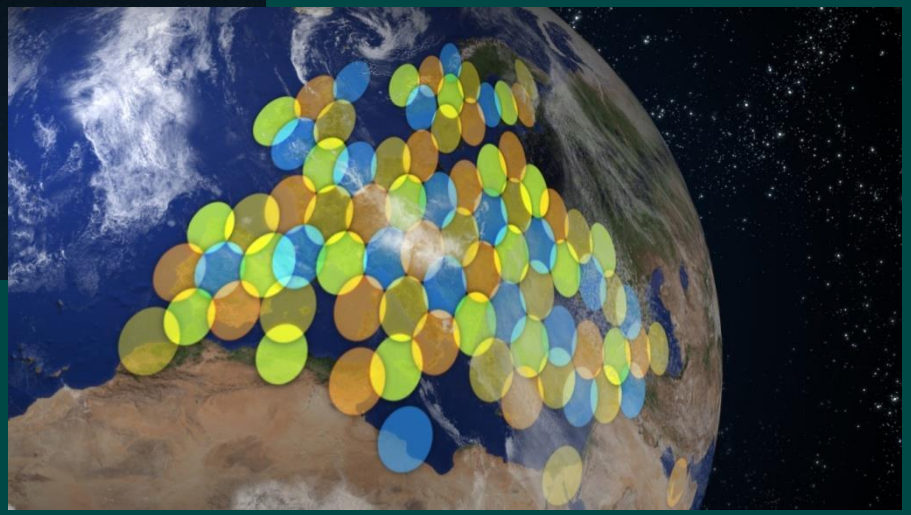
The British military's Skynet 5 satellite system is based on this. The spacecraft is part of a £3.6bn system that will deliver secure, high-bandwidth communications for UK and allied forces.

Eutelsat's Ka-SAT is one of the world's most powerful satellites, with a total capacity of more than 70 Gbps, 35 times the throughput of traditional Ku-band satellites.



KA-SAT will provide ubiquitous complete coverage of Europe and the Mediterranean Basin through its 82 spot beams in Ka-band

ViaSat-1 in the Compact Antenna Test Range (CATR) - Space Systems/Loral

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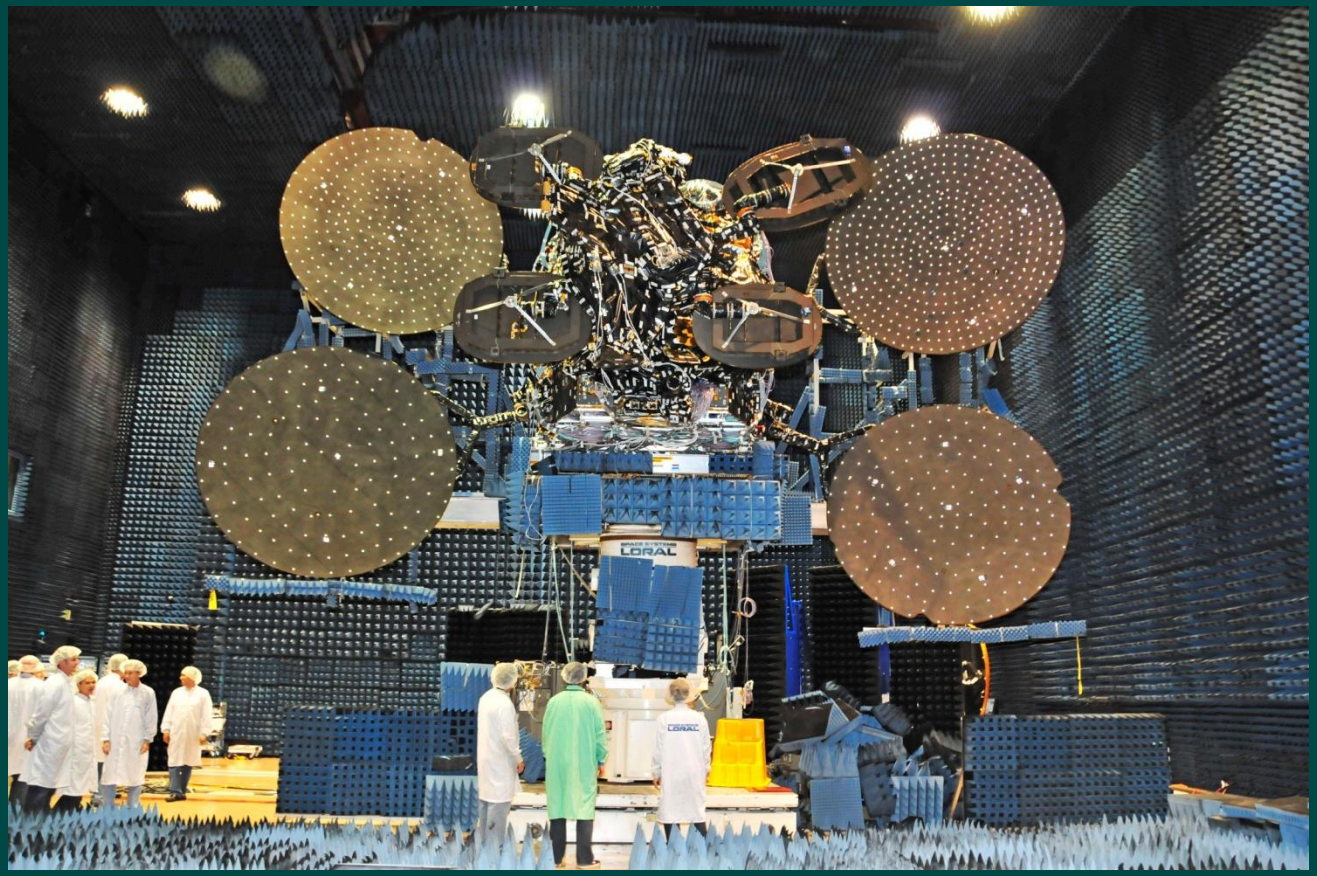


ViaSat-1, which will be positioned at 115.1 degrees West longitude, is expected to provide more than 100 gigabits per second throughput in the Ka band, mostly for use in the West Coast of the U.S. and east of the Texas panhandle. The satellite has 72 spot beams, with 63 in the U.S. and nine over Canada.

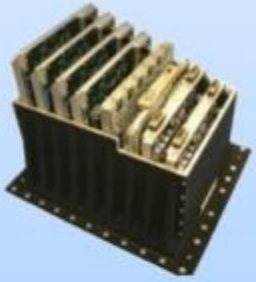
Space Router –
A Software Defined Architecture

Any-Frequency Transponders

X | C | Ku | Ka

Modem Interface Chassis (MIC)

- Modem (TDMA)
- Modem (SCPC)



Route Processing Engine (RPE)

- Services
- Control Plane (Dynamic Routing)

Software Defined Architecture

Future-Proofing Satellites with Upgradeability in Space
Cisco IOS Software and Modem Waveforms

Traditional Satellite Networking (Left) vs. IP-Based Satellite Networking (Right)

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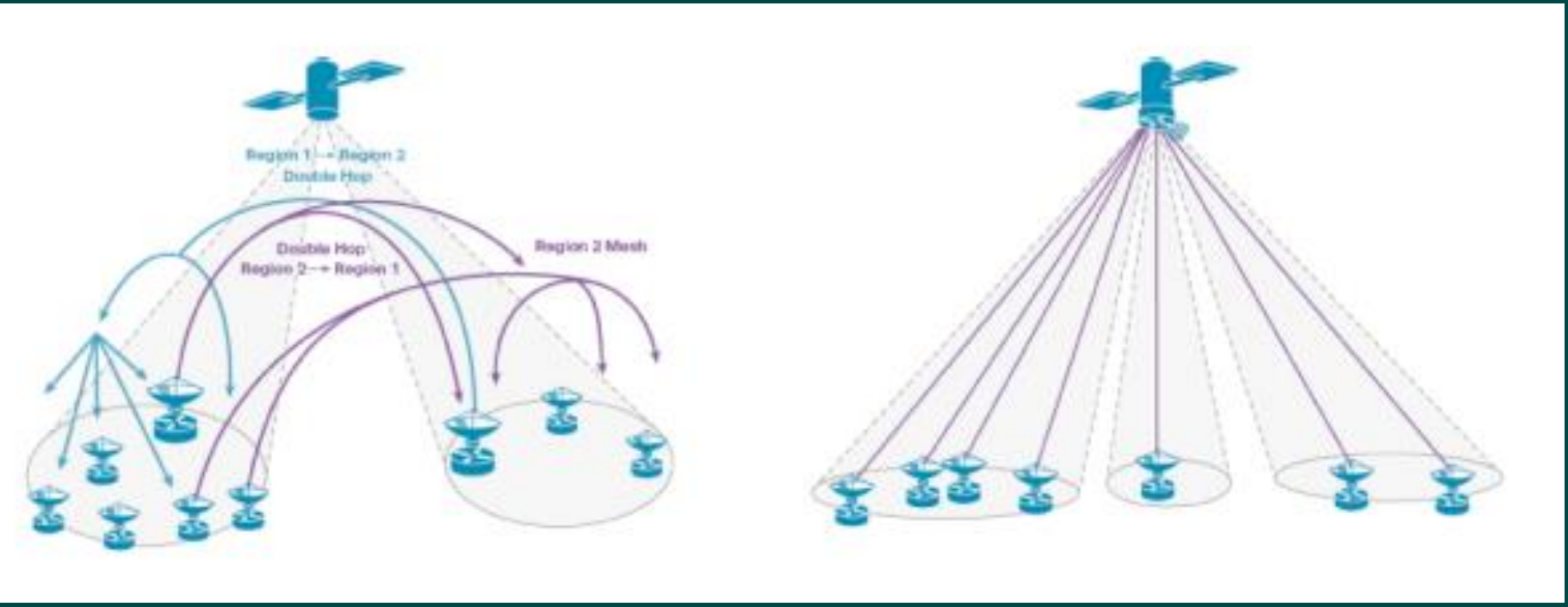

The Space-Ground Architecture Enabled by Cisco IRIS

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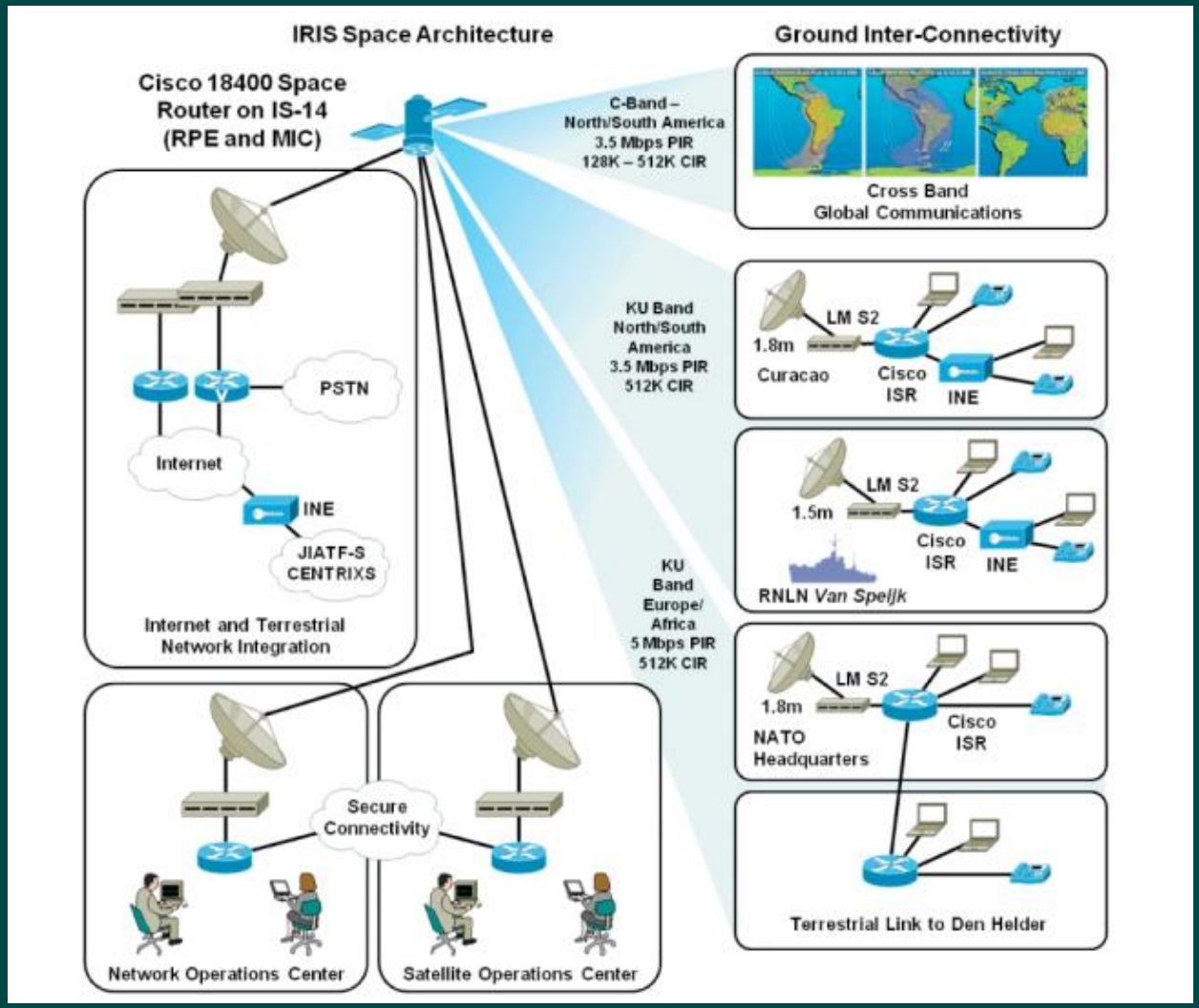

The Intelsat Satellite Network 2008

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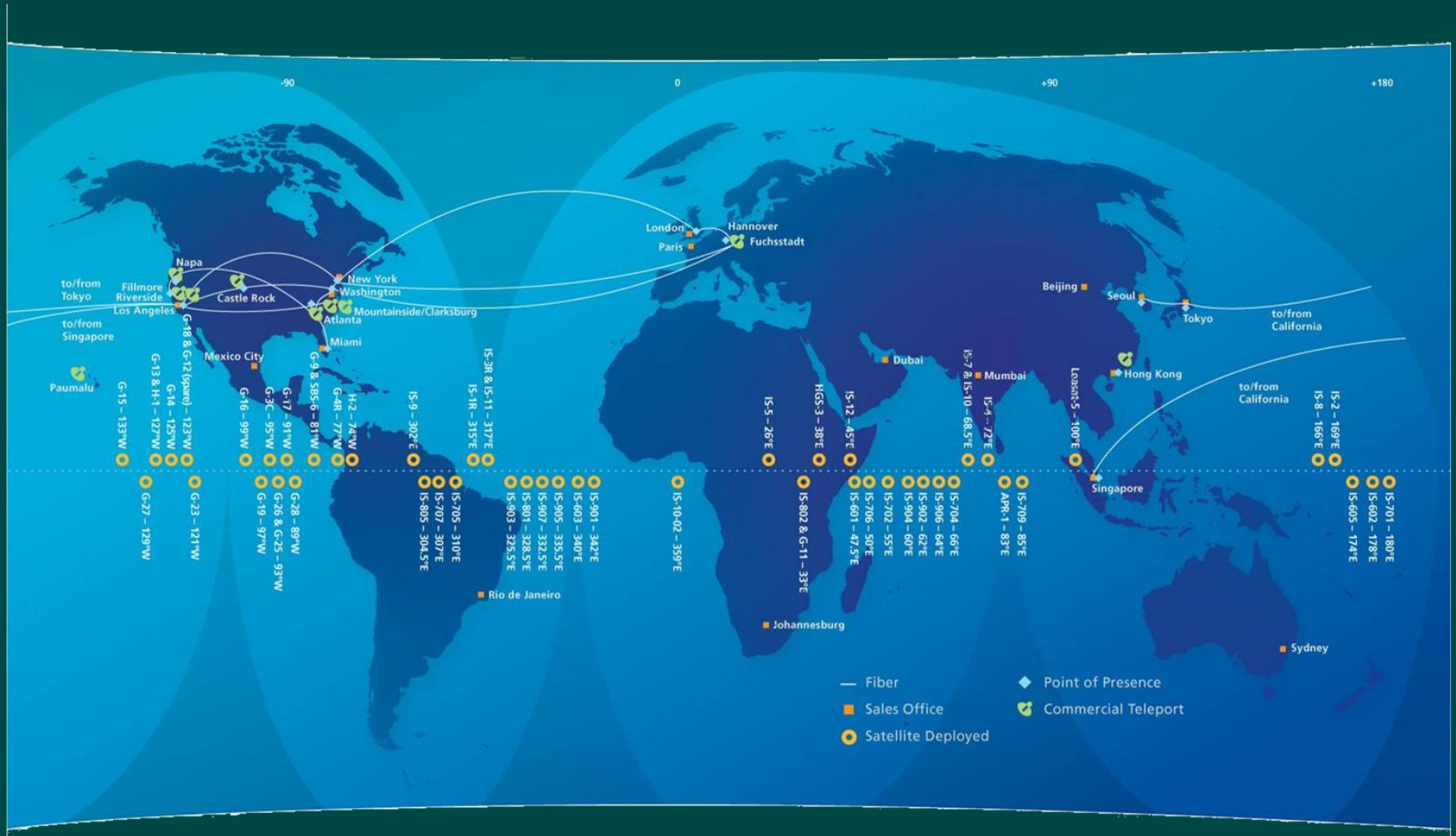

Very Small Aperture Terminal (VSAT)

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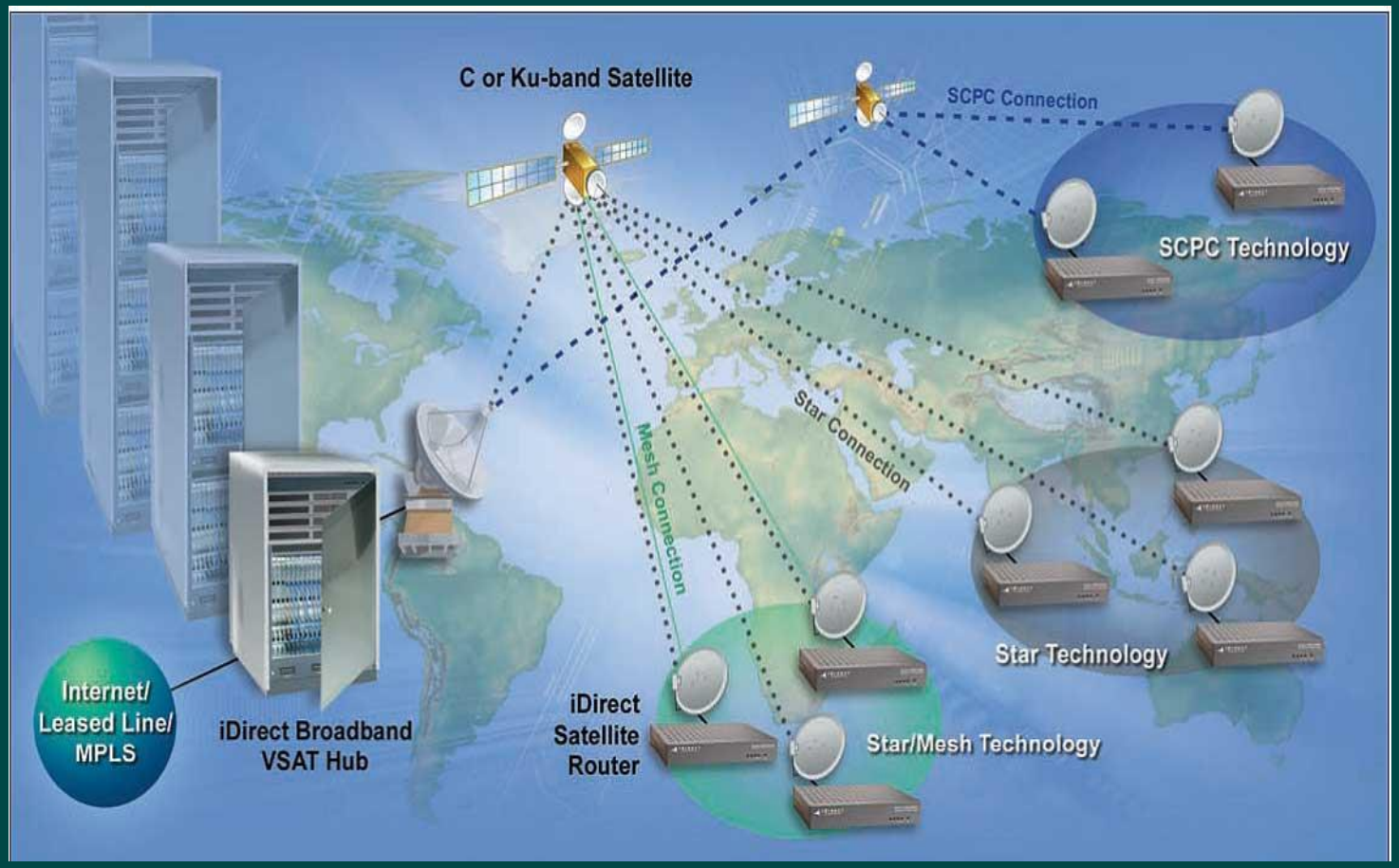

Intelsat GXS® Fiber Network

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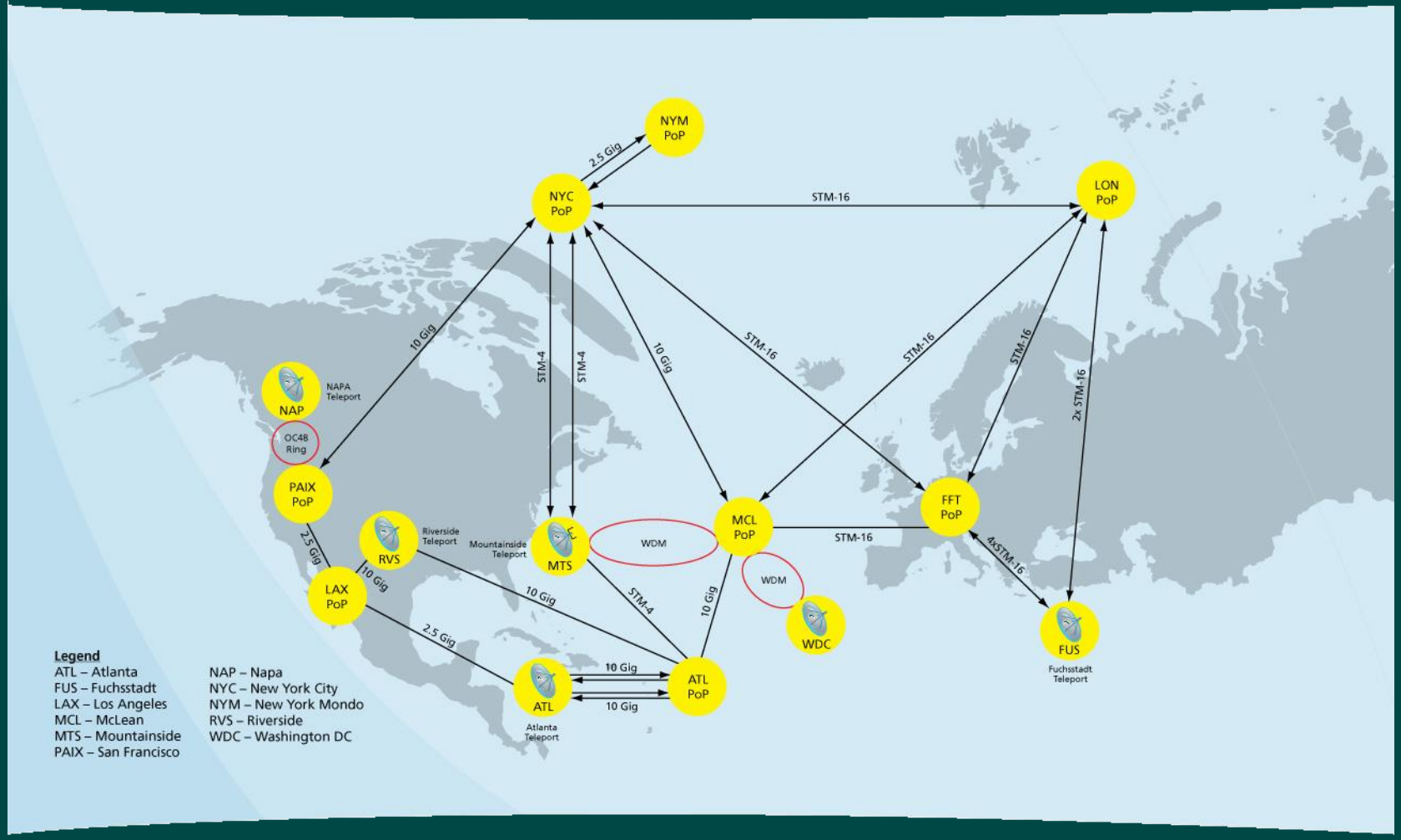

Intelsat GXS® IP Network

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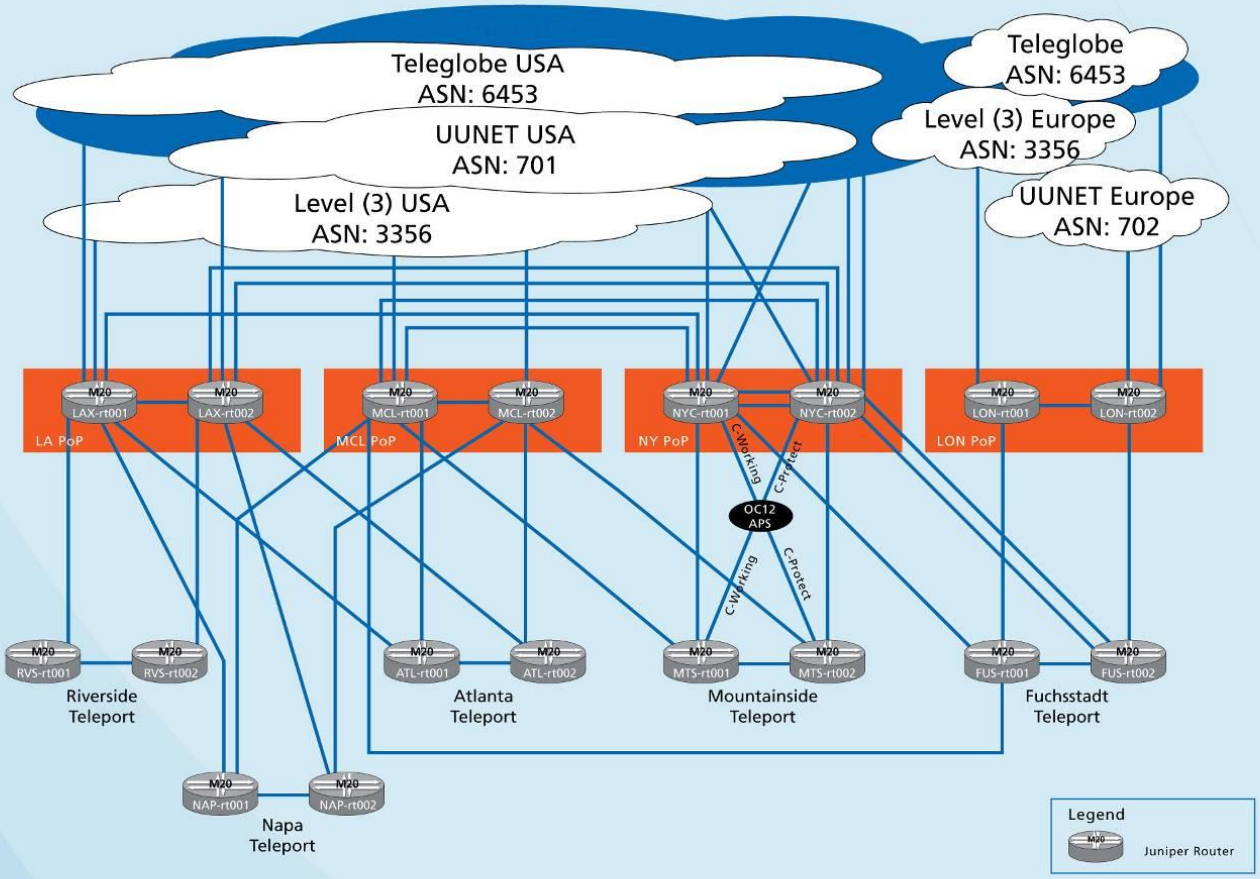

Satellite Communication Systems Integrate into the Global Fibre Backbone

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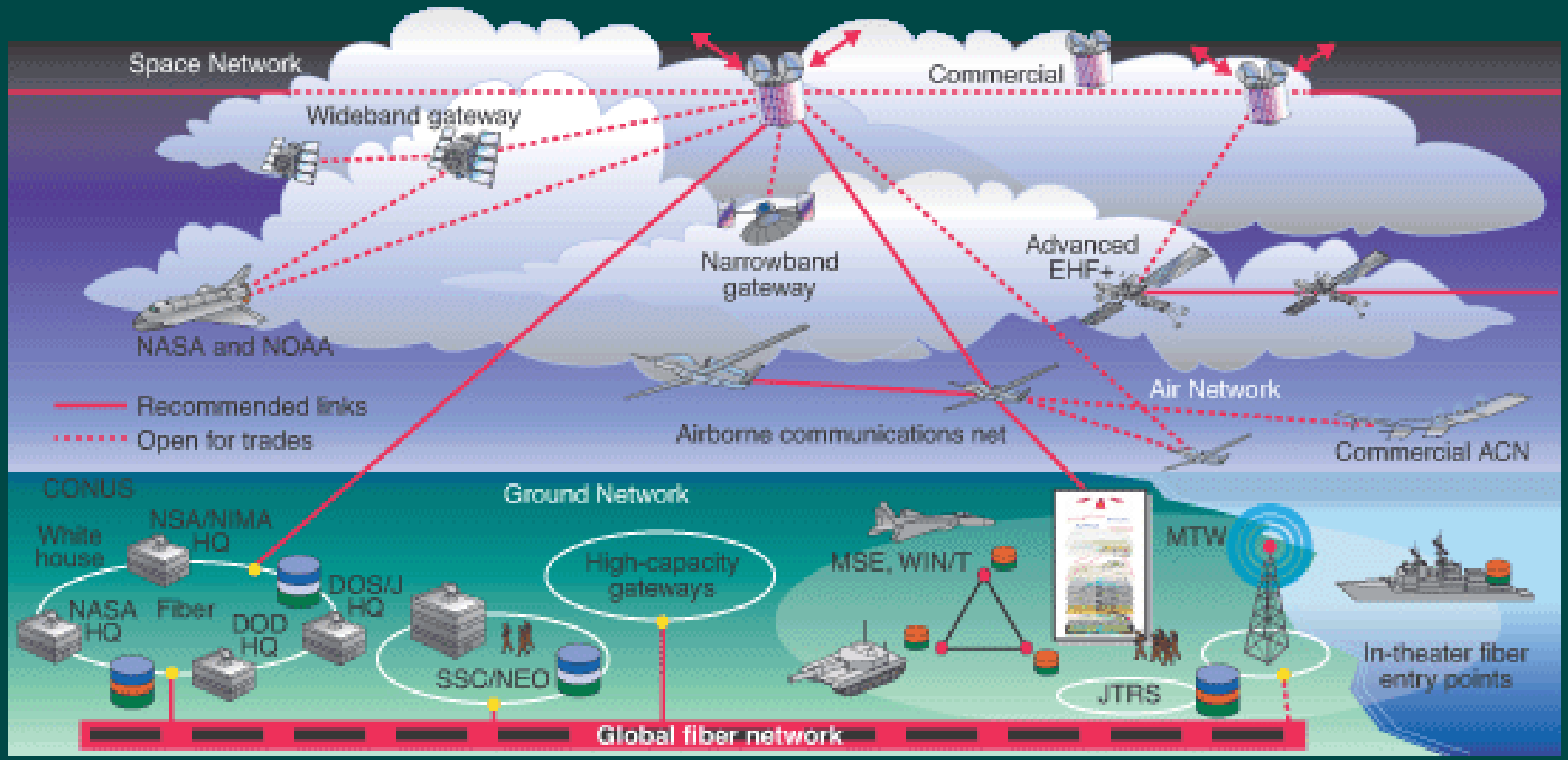

DWDM Optical Fibre Communications
- Capacity: 7.1 terabytes per second Dec 2007
Fundamental element of Panopticon

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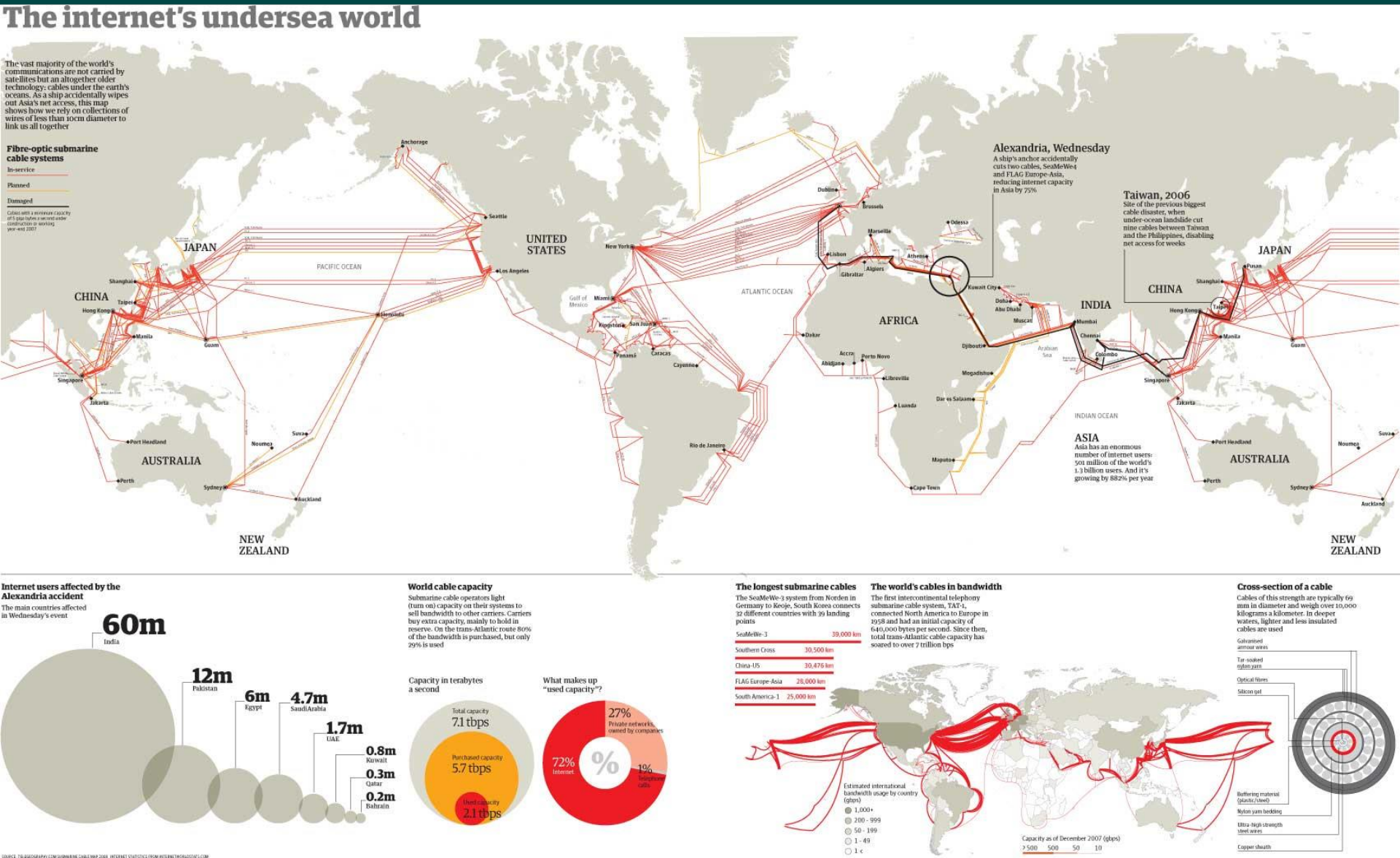

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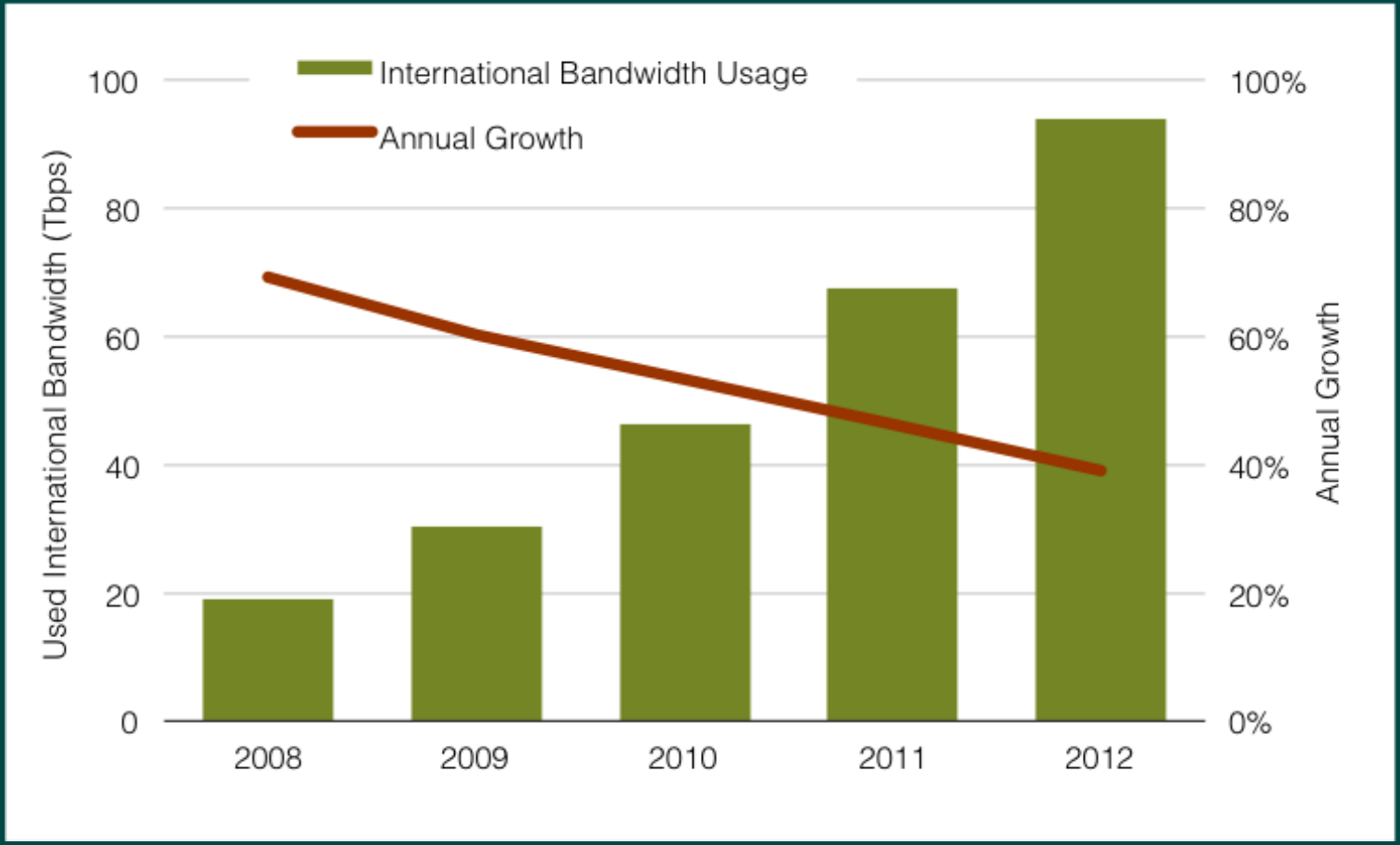

crciimsoc040101

Arctic Fibre is deploying state of the art technology utilizing 100 gigabit wavelengths to construct a system with a capacity of 24 terabits/s.

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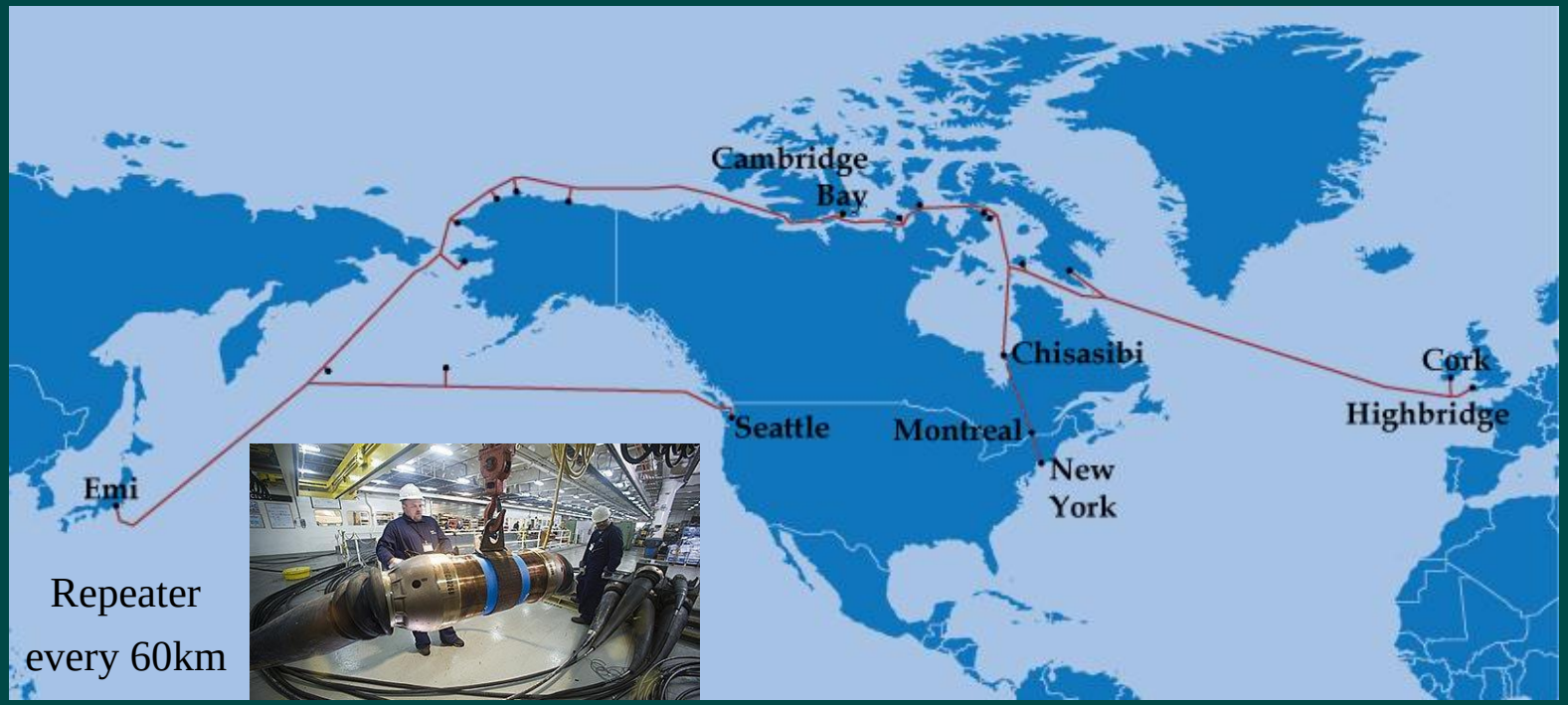
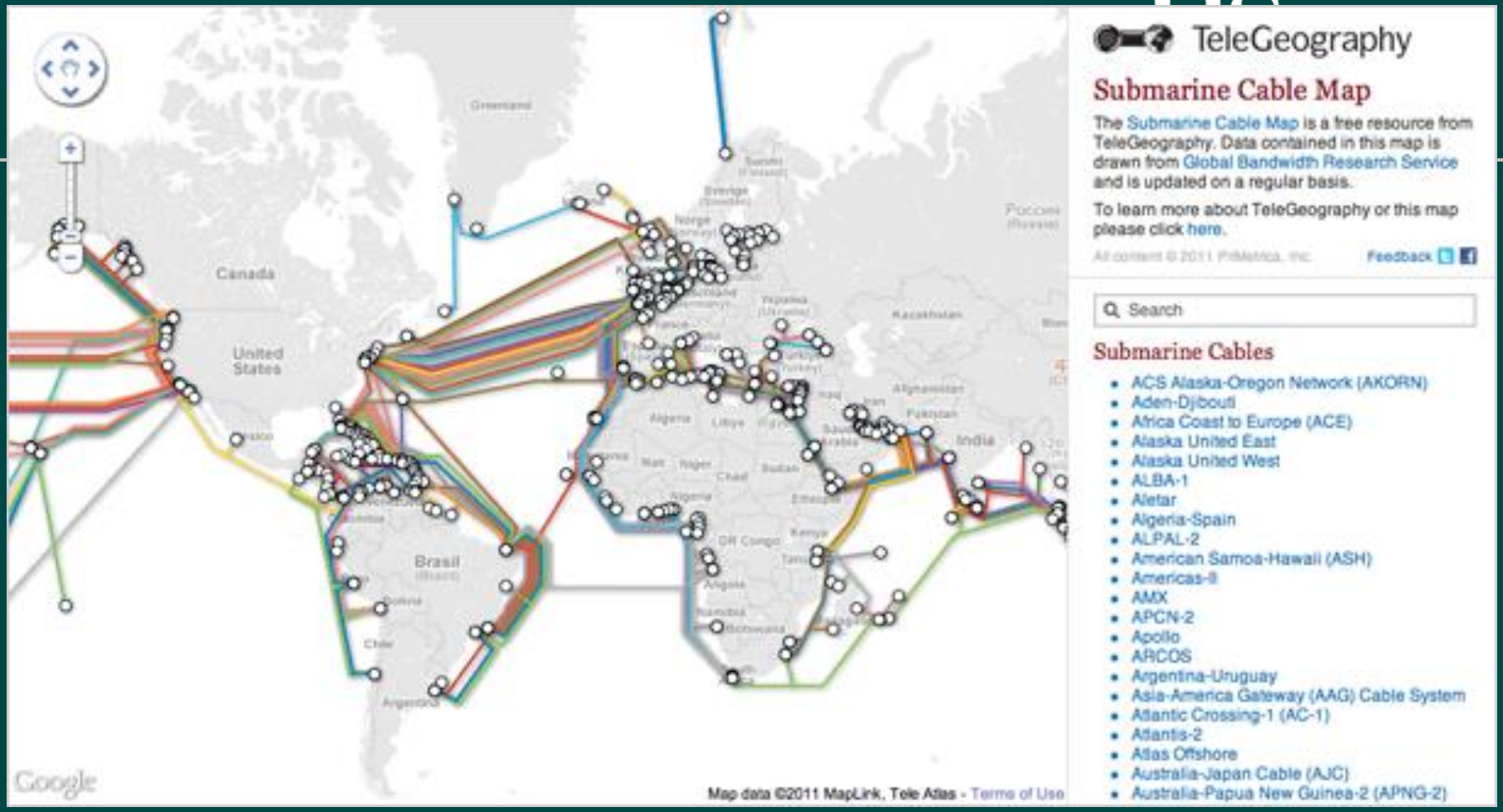


The construction of the system is beginning in May 2014 and is scheduled to be in service in January 2016.



http://www.submarinecablemap.com/

More than adequate terabyte capacity at the shores of Africa

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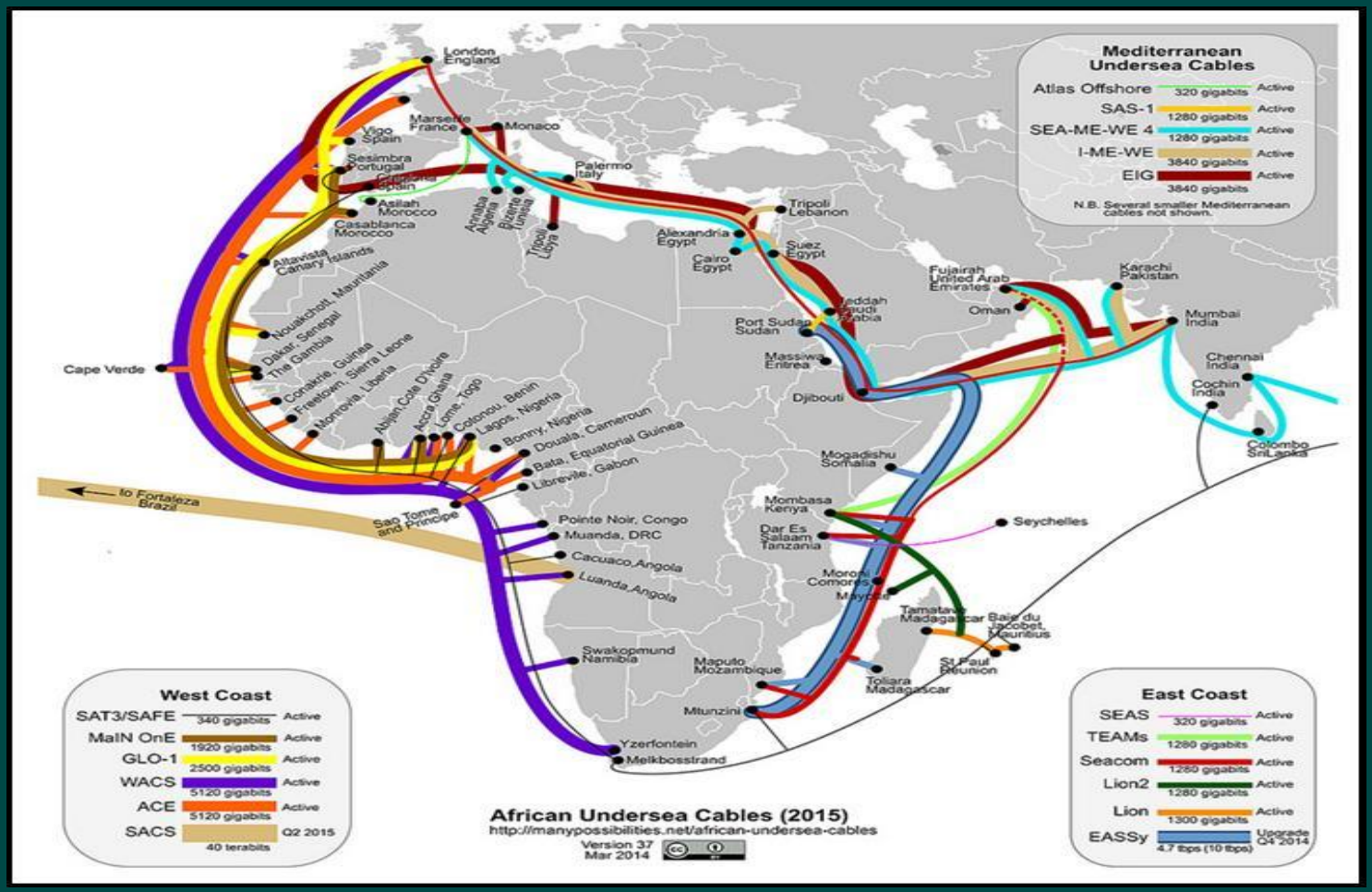

✓WEST COAST: OVER 15TBPS AND 55 TBPS BY 2Q OF 2015

✓EAST COAST: 10.160TBPS AND 15.460 TBPS BY 4Q OF 2014

✓MEDITERRANEAN : 10.56TBPS

Nigerian Satellite Communication System

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- NIGCOMSAT-1 was launched 13th May, 2007 GMT Nigerian time and was de-orbited on 10th November, 2008 due to in-orbit subsystem anomaly – After launch satellite internet prices almost halved, then increased by 50% when it was de-orbited.

- Nigcomsat-1R was launched on 20th December 2011.(GMT) Nigerian time but early hours of 21st December, 2011 Chinese Local Time. Internet connection charges decreased considerably.

Nigcomsat-1R Satellite up to 5 Gbps

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Nigcomsat-1R Satellite – 9kW quad band

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- C-Band Transponder – 4 active transponders - 36MHz
- Ku-Band Transponder – 14 active transponders – 31.5MHz
- Ka-Band Transponder and – 8 active transponders – 120MHz
- L-Band (Navigation) Transponder – 2 active transponders
- Seven (7) Service Antennas
- NigComSat-1R with service life of more than 15 years has a designed life of 22.5 years with more than 0.70 reliability value at the end of its service life.

Nigcomsat-1R Footprints and Coverage

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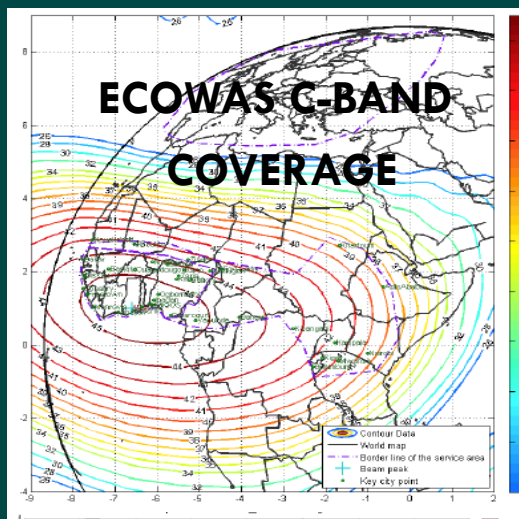

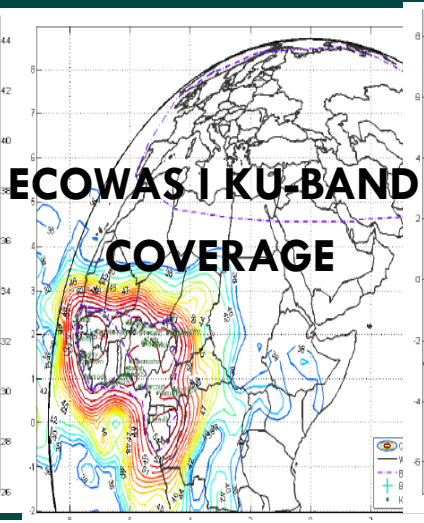

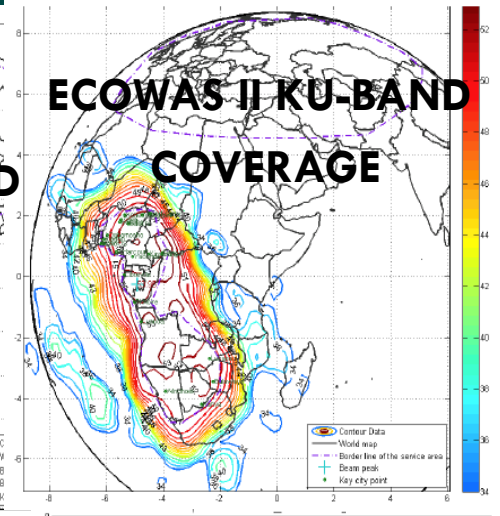

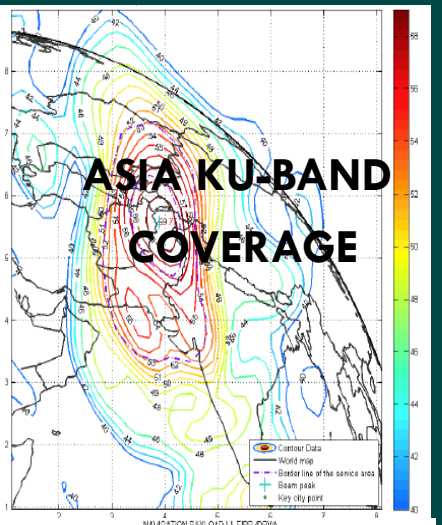

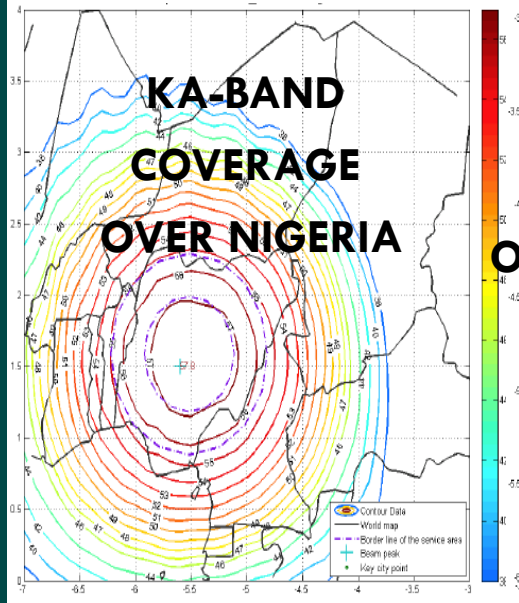

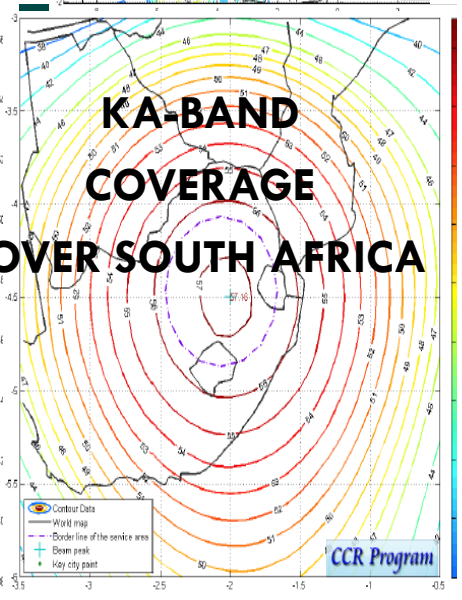

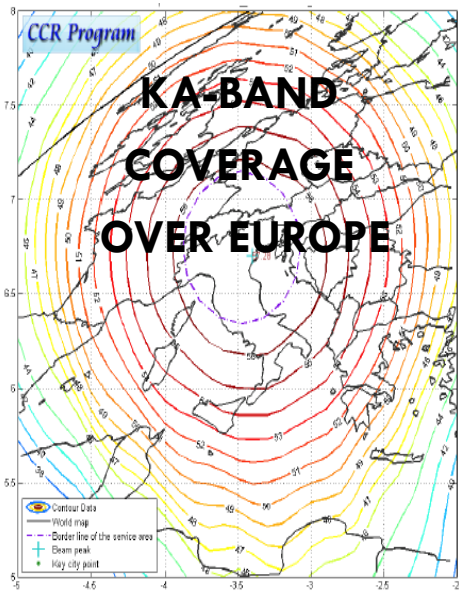

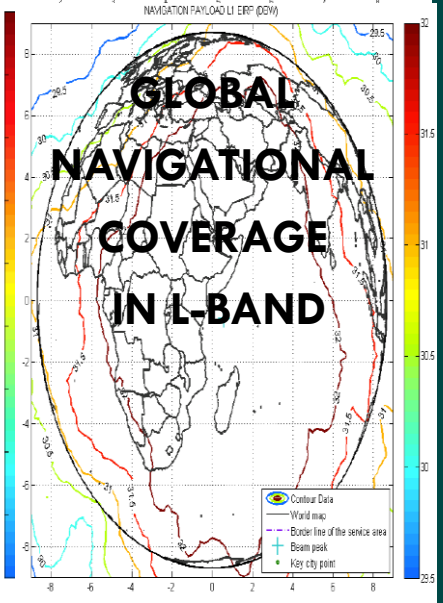

Global Data Integration Technology

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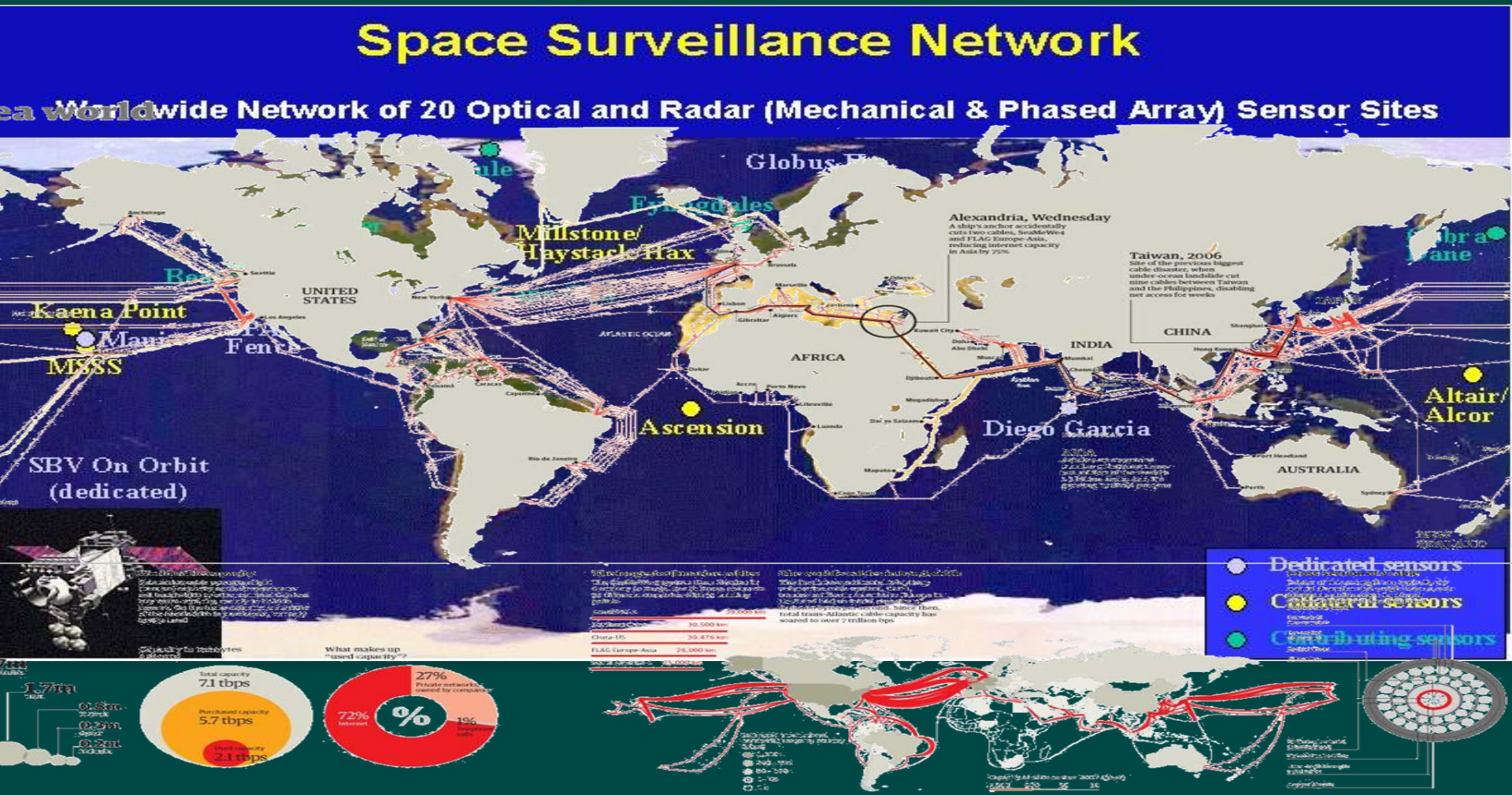

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GCHQ

GCHQ's headquarters are in Cheltenham, Gloucestershire. There are two much smaller sites in Cornwall and Yorkshire but most of the 5500 staff work at the impressive state of the art building at Benhall in Cheltenham.

Trans-Atlantic Fibre Optic Cables

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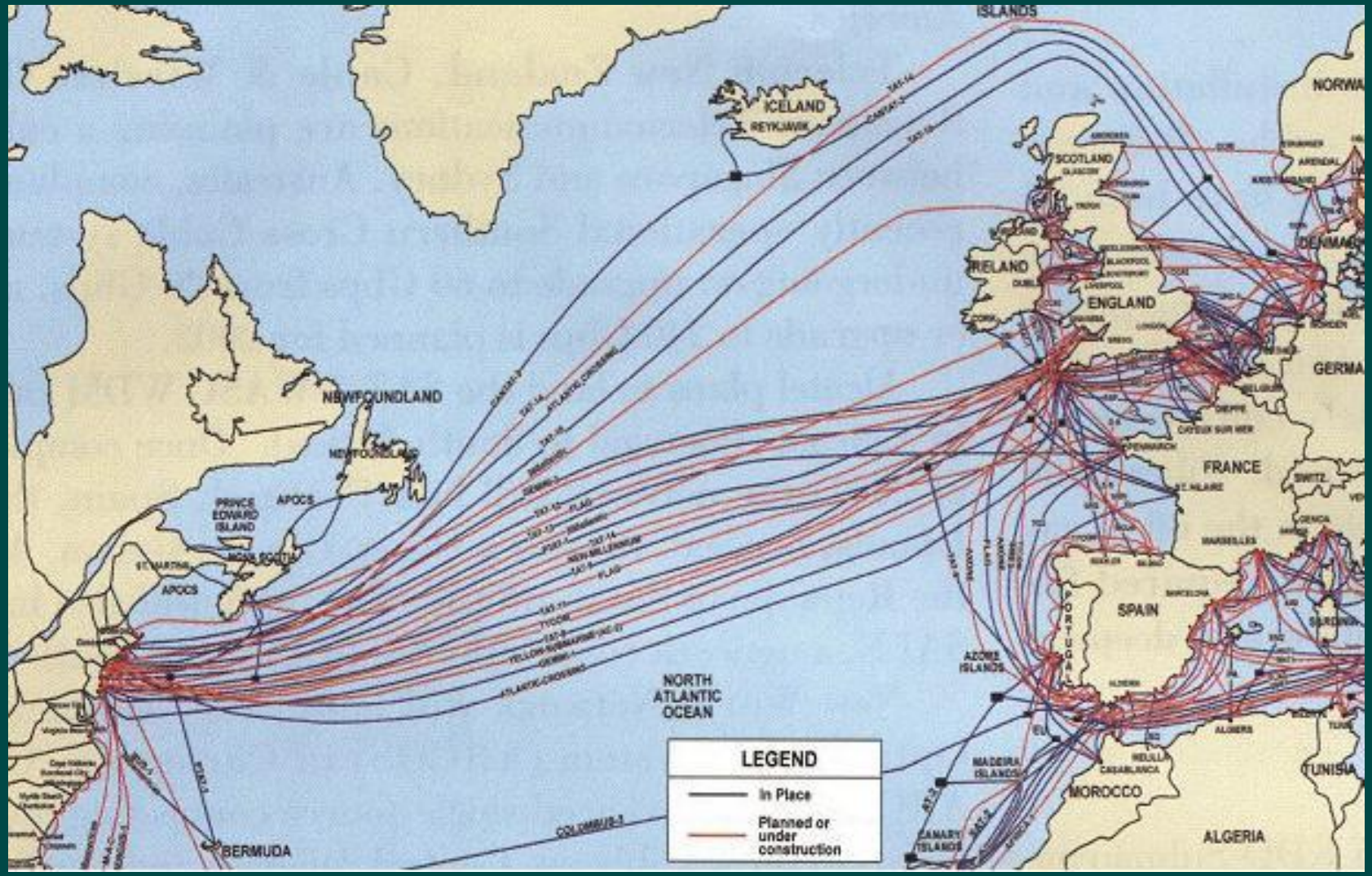

The 9,300 square metre data centre near Frankfurt – requires a reliable power supply

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- European data centres consumed 56TWh of electricity in 2007 and in the UK they are responsible for almost three per cent of electricity use.

Rocket Propulsion Systems

International Space Station

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International Space Station

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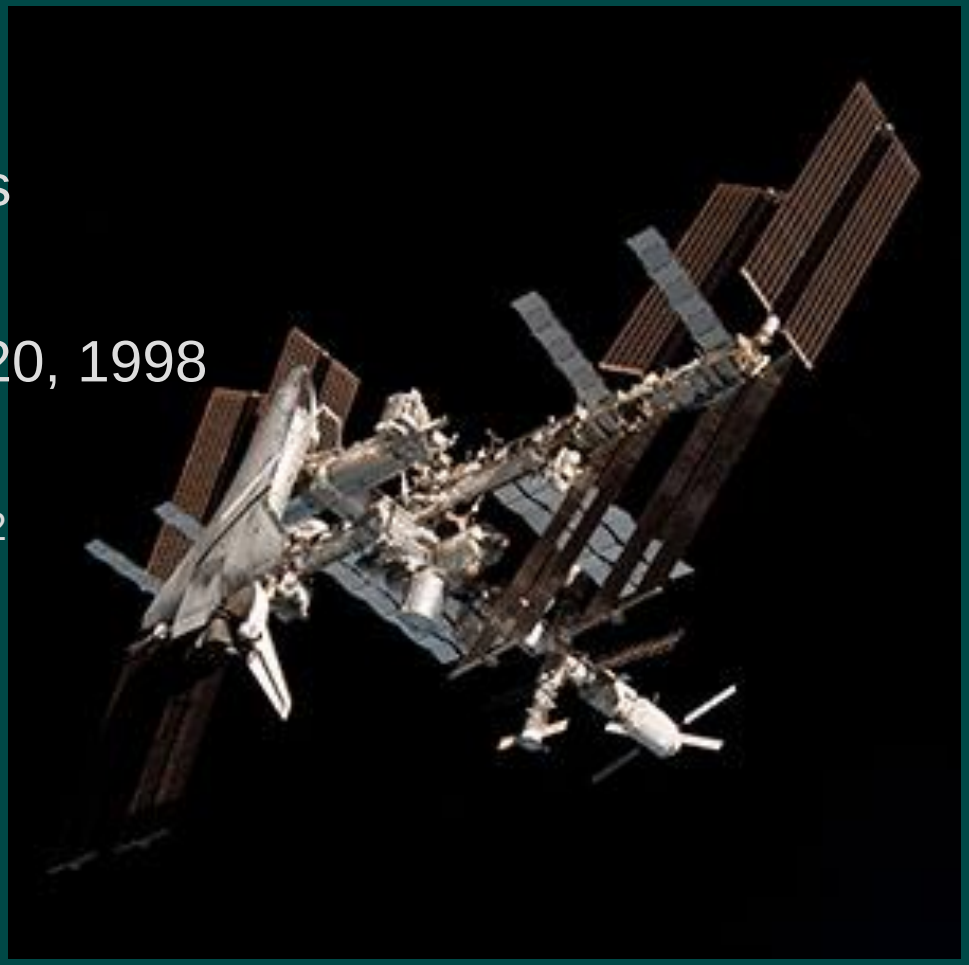
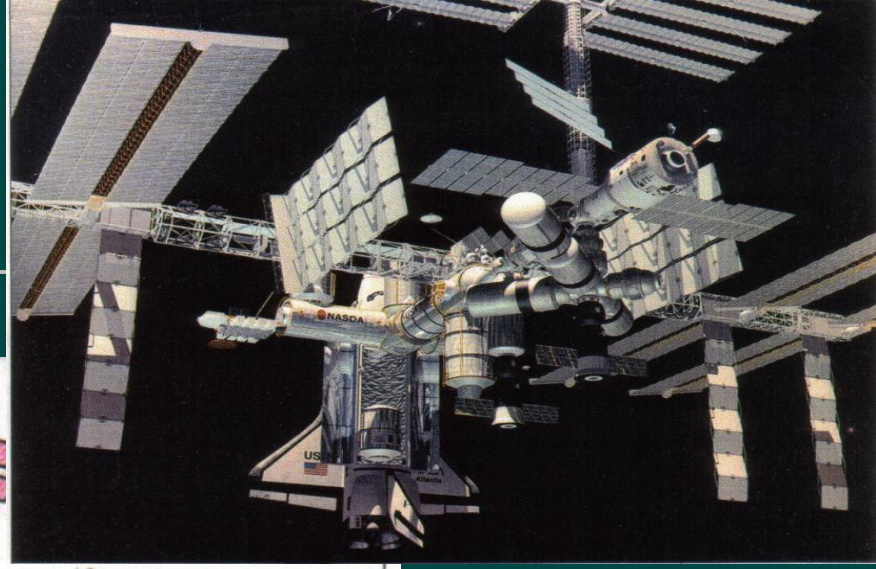
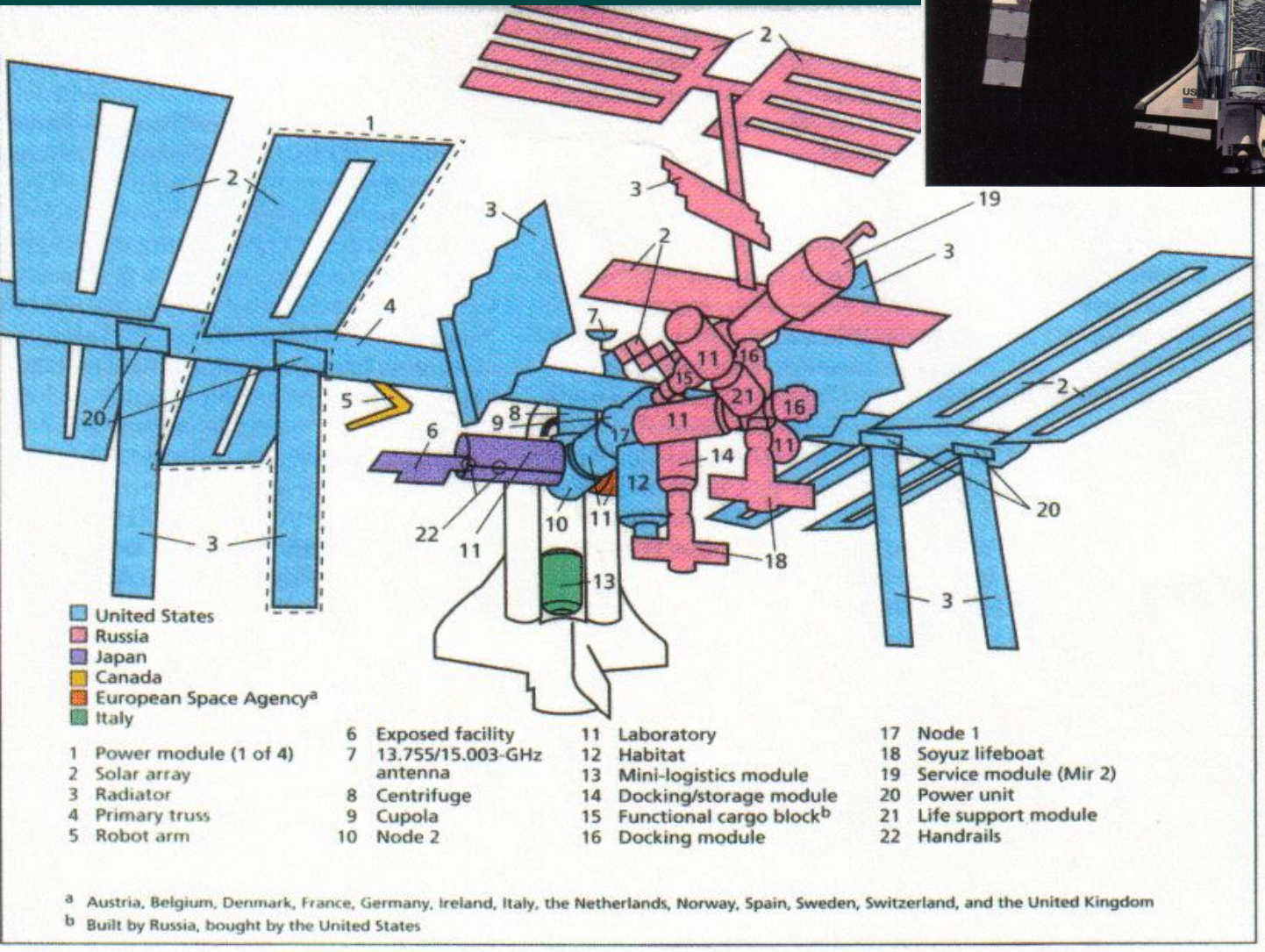
- **Orbit height:** 431 km
- **Speed on orbit:** 7.66 km/s
- **Max speed:** 27,600 km/h
- **Launch date:** November 20, 1998
- **Cost:** 150 billion USD
- Solar panel array 4,000 m^2



International Space Station





[a] Austria, Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom

[b] Built by Russia, bought by the United States

Mars Landing:

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Aspects to consider:

Little atmosphere- can use parachute to reduce speed but need retrorocket and/or, as on Pathfinder, used bouncing ball cushions to withstand landing shock (originally used by Russians on moon landings).

Landing zone inclination-craters, rocks, etc.

Low solar constant → Power requirements

Low temperatures

Dust storm effects on sensitive optics.

Rovers, power requirements, autonomous movement, telemetry back, etc.

Exploration considered by long distance rover, Balloon, aircraft, etc

Mars Landing:

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Earth-Mars planet alignments favour launches every 2+ years.
Use Phobos and Deimos as staging posts/stations for exploration of Mars?
Life on Mars? Most likely place to look in solar system.

NASA Sample return mission 2011. Return: dock with mars orbiter [difficult!]

Avoid contamination of samples>Earth Orbiter? quarantine?

Closest planet and most likely destination for manned missions beyond moon →

new US initiative & ESA Aurora project → probably international(US lead) ~2025

Far future: generate return fuel at Mars from Mars materials (CO & O_2 ?).

Mars Express

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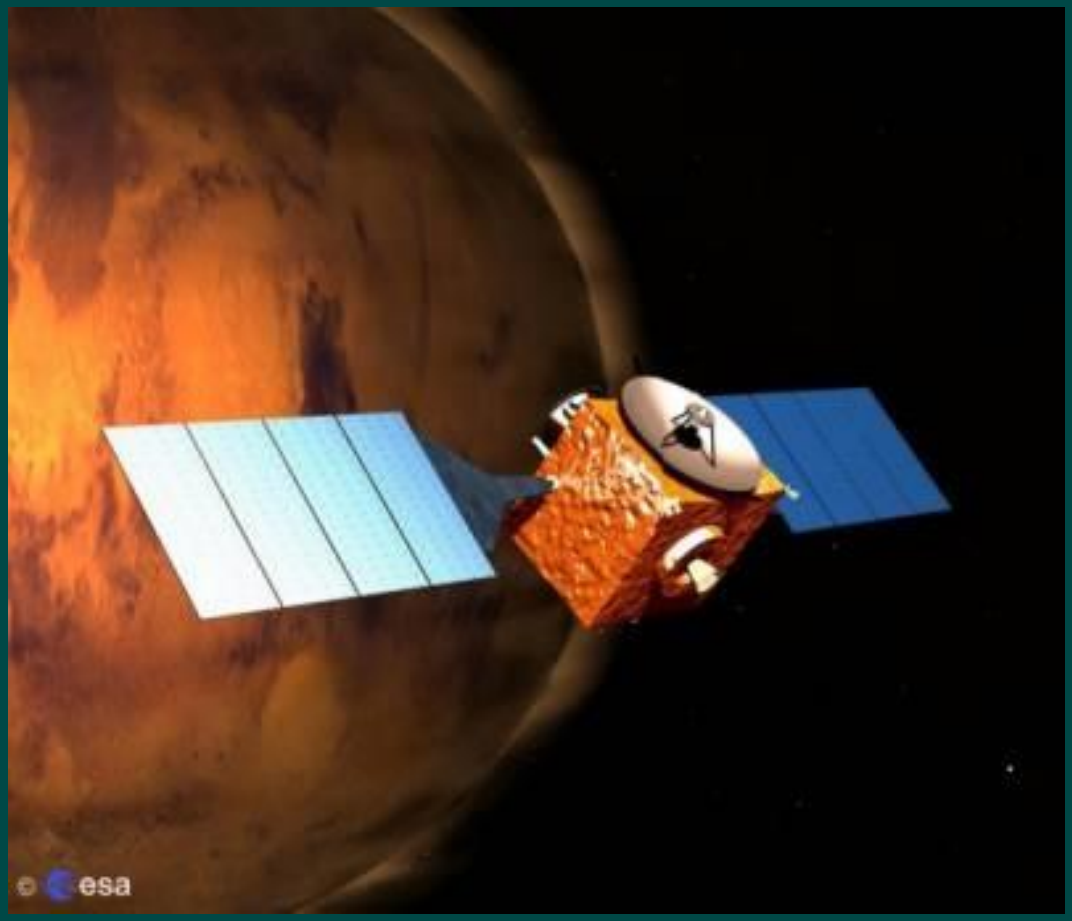

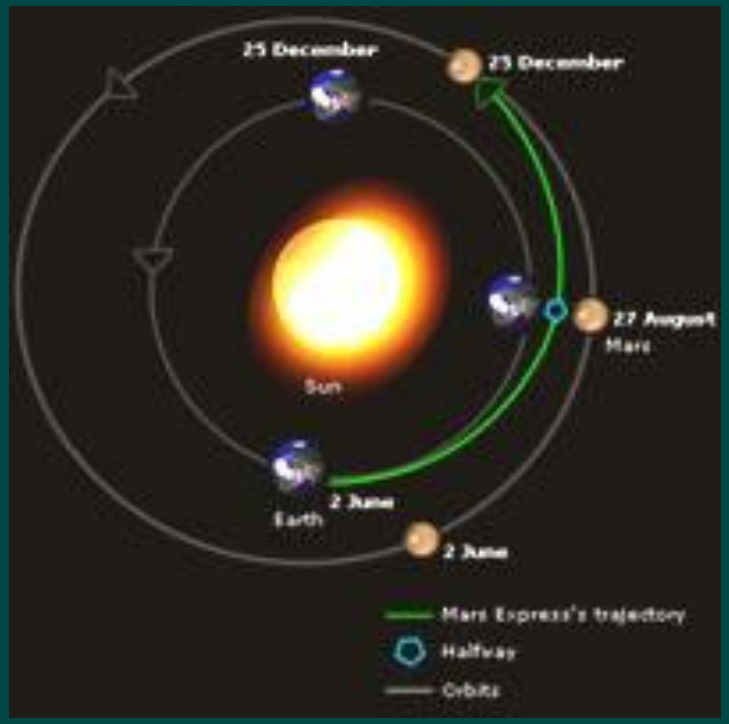

Mars Express

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High Resolution Stereo Camera (HRSC)

The HRSC is imaging the entire planet in full colour, 3D and with a resolution of about 10 metres. Selected areas will be imaged at 2-metre resolution.

Mars North Pole 12kM dia Water Ice Lake

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Mars Express view of Olympus Mons

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Nasa's experiment to find water on the Moon was a major success

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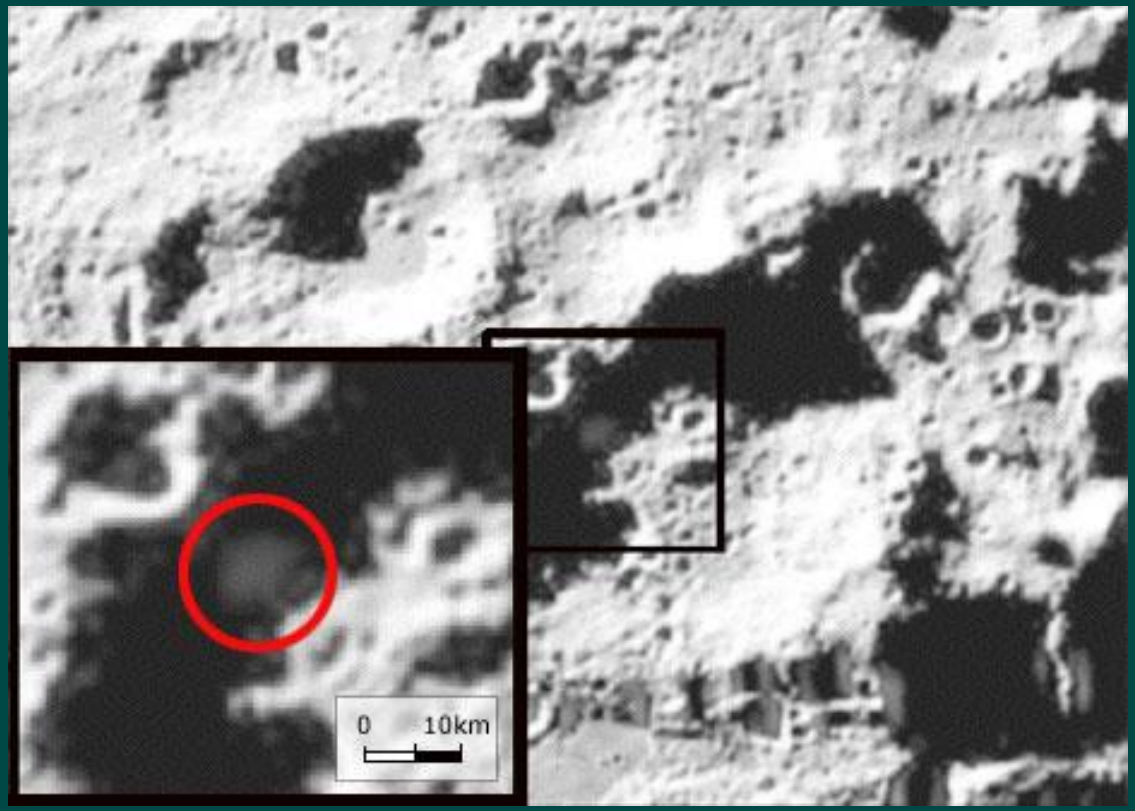

A camera on the probe shows the ejecta plume about 20 seconds after impact

The space agency smashed a rocket and a probe into a large crater at the lunar south pole, hoping to kick up ice.

Scientists who have studied the data now say instruments trained on the impact plume saw copious quantities of water-ice and water vapour.

Titan

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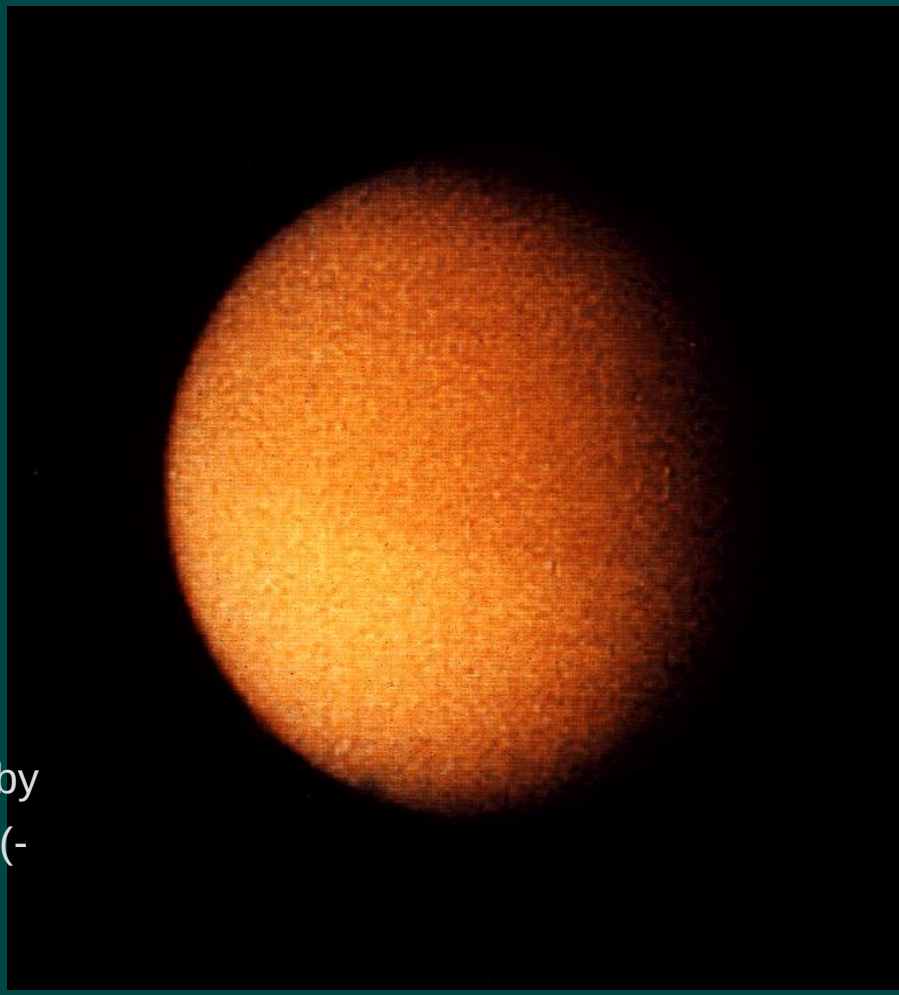
Titan, (size>Mercury,<Mars) is the only body in the solar system, other than Earth, that may have oceans and rainfall on its surface, but oceans & rain of ethane- methane rather than water.

Present environment <-180^{o}Cdegrees, so cold that water ice would be as hard as granite – might be similar to that on Earth billions of years ago, before life began pumping oxygen into the atmosphere. Titan's atmosphere, 4 bar, mainly N_2+ trace methane and ethane -> thick, orange, hydrocarbon haze (impenetrable to cameras) (similar to terrestrial smog methane dissociated by sunlight) . 16day orbit, possible rotation rate16d (-> same side to Saturn).

NASA/ESA Cassini Mission launched Oct 97 with ESA Hygens probe to enter Titan atmosphere in, battery power 600W-



Mission aims for Titan:

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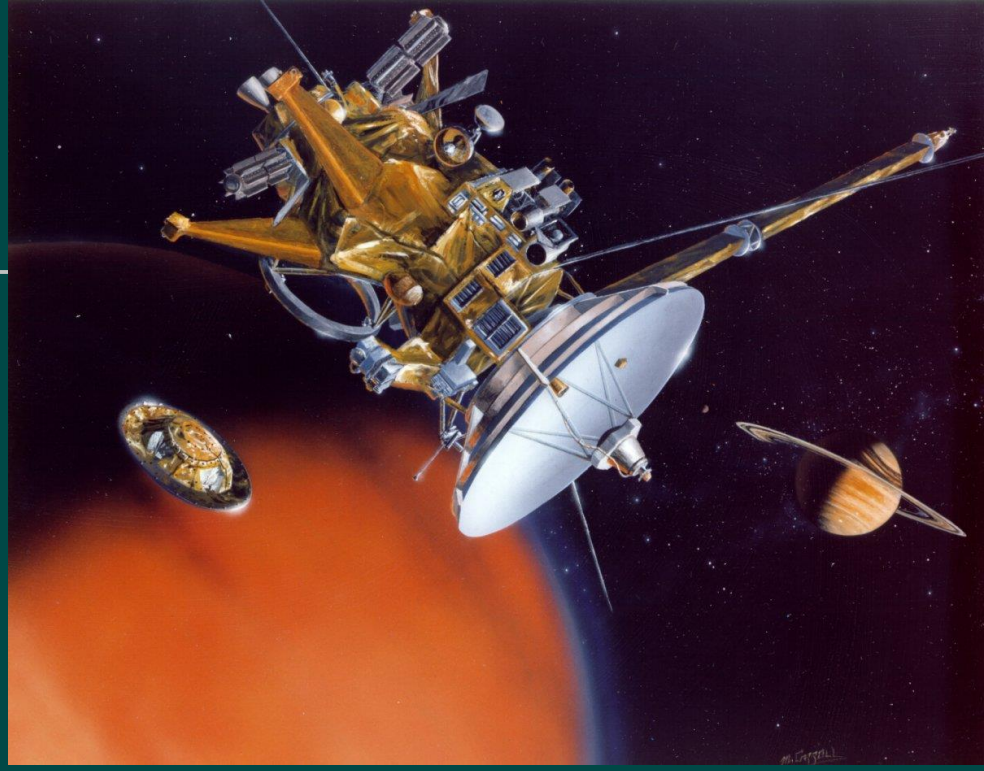
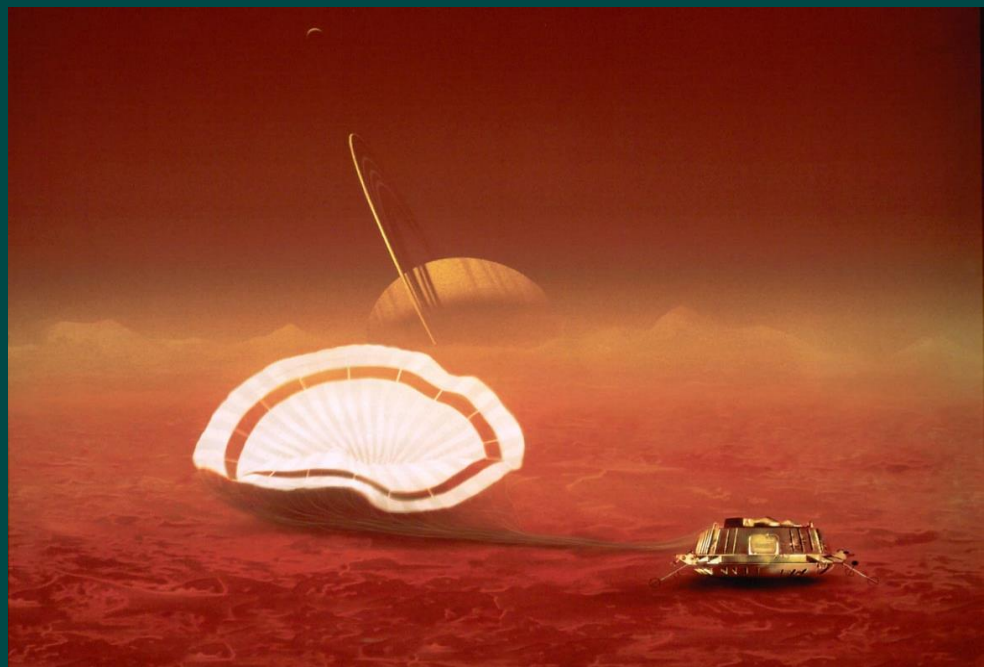
(1) determine density, pressure, temperature, etc. of atmosphere as a function of height;
(2) measure constituents of atmosphere
(3) investigate the atmosphere's chemistry /photochemistry, organic molecules & smog
(4) meteorology: cloud physics, lightning discharges, and general circulation;
(5) examine the physical state, topography, and composition of the surface.

ESA Huygens probe

ESA Huygens is 1.3 m diameter descent module with a spherical nose and a conical aft section. A thermal protection aeroshell surrounds the descent module,slowing it from 6 Km/s at arrival to 400 m/s in about two minutes and protecting it from the heat of entry. A parachute then deployed and the aeroshell jettisoned. The probe floats down through the atmosphere.

Instrumentation for the probe includes: an aerosol collector and pyrolyzer, a descent imager and spectral radiometer, a Doppler wind experiment, a gas Chromatograph /mass spectrometer, an atmospheric structure instrument, and a surface science package.





NASA Cassini to Saturn & ESA Huygens probe to Titan

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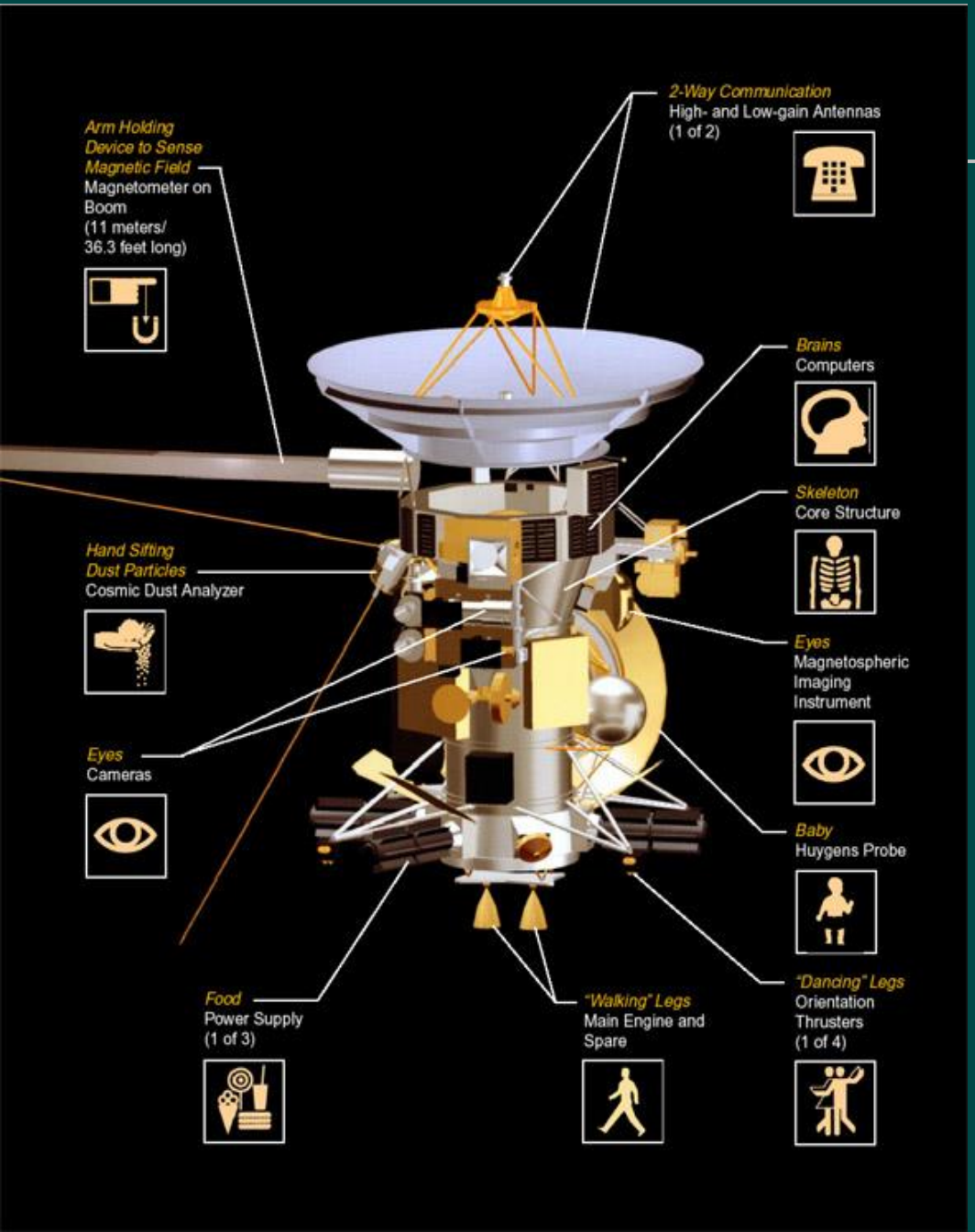

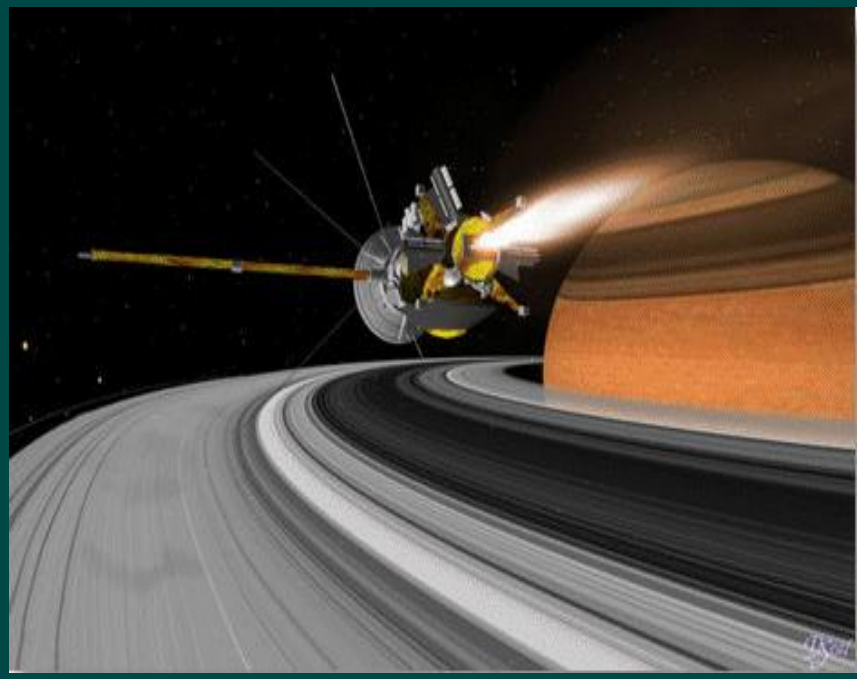

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Cassini-Huygens Spacecraft

Structures and Materials

Science Data Networks

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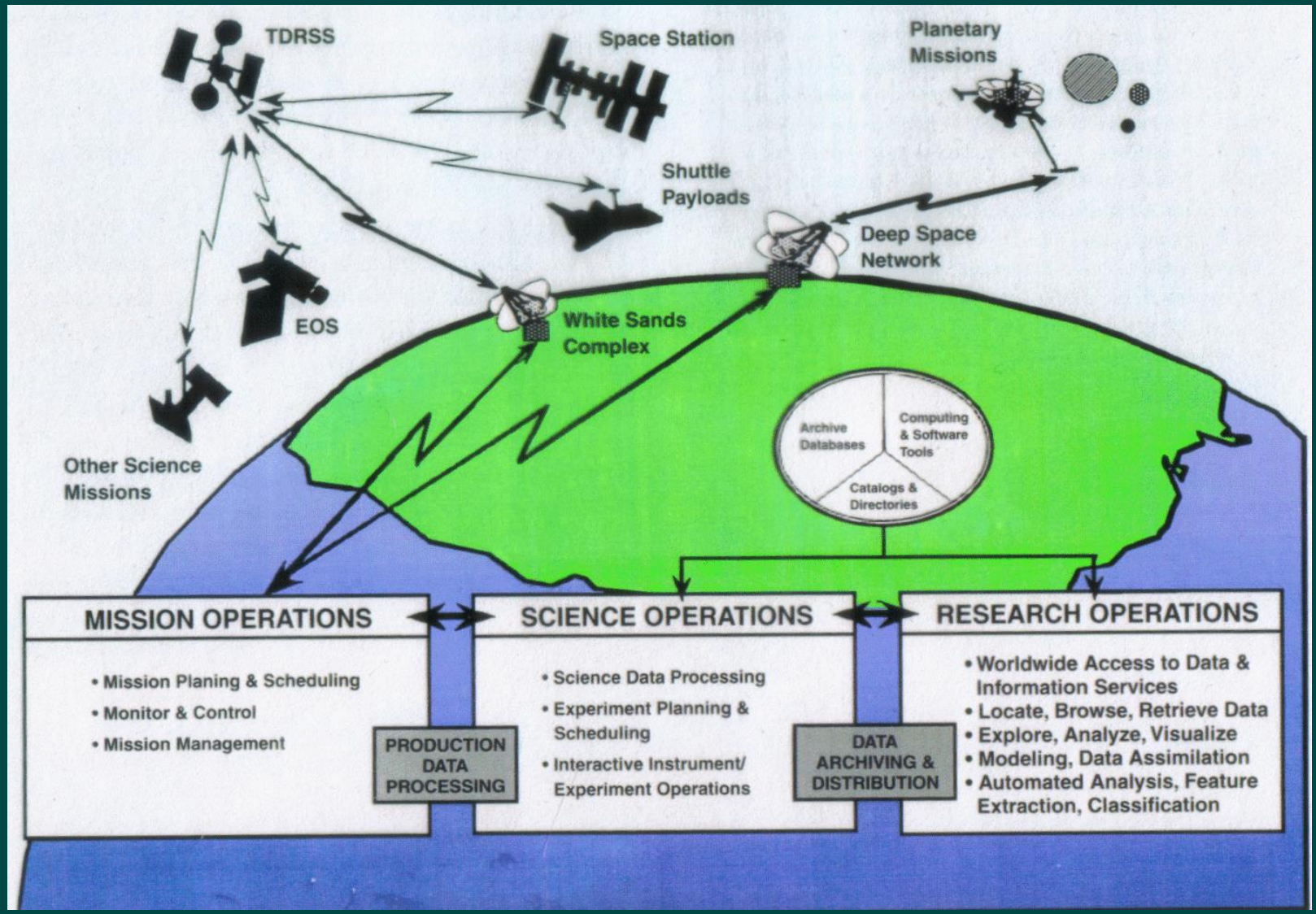
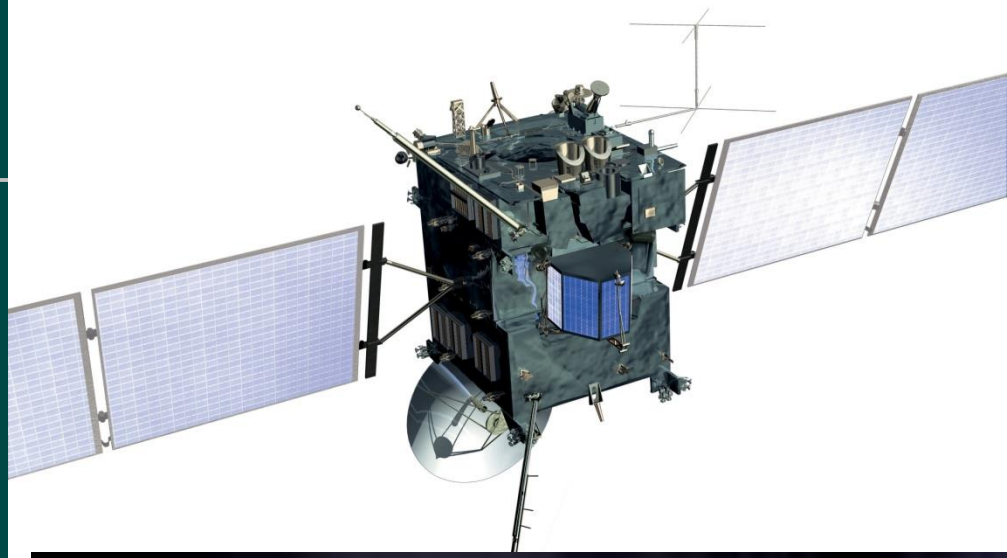


Comets



Giotto probe to Comet Halley (above) & Rosetta Comet mission,2004 (right), including lander on comet nucleus.
Comets - left over from early solar system

Gravity Recovery And Interior Laboratory (GRAIL) NASA

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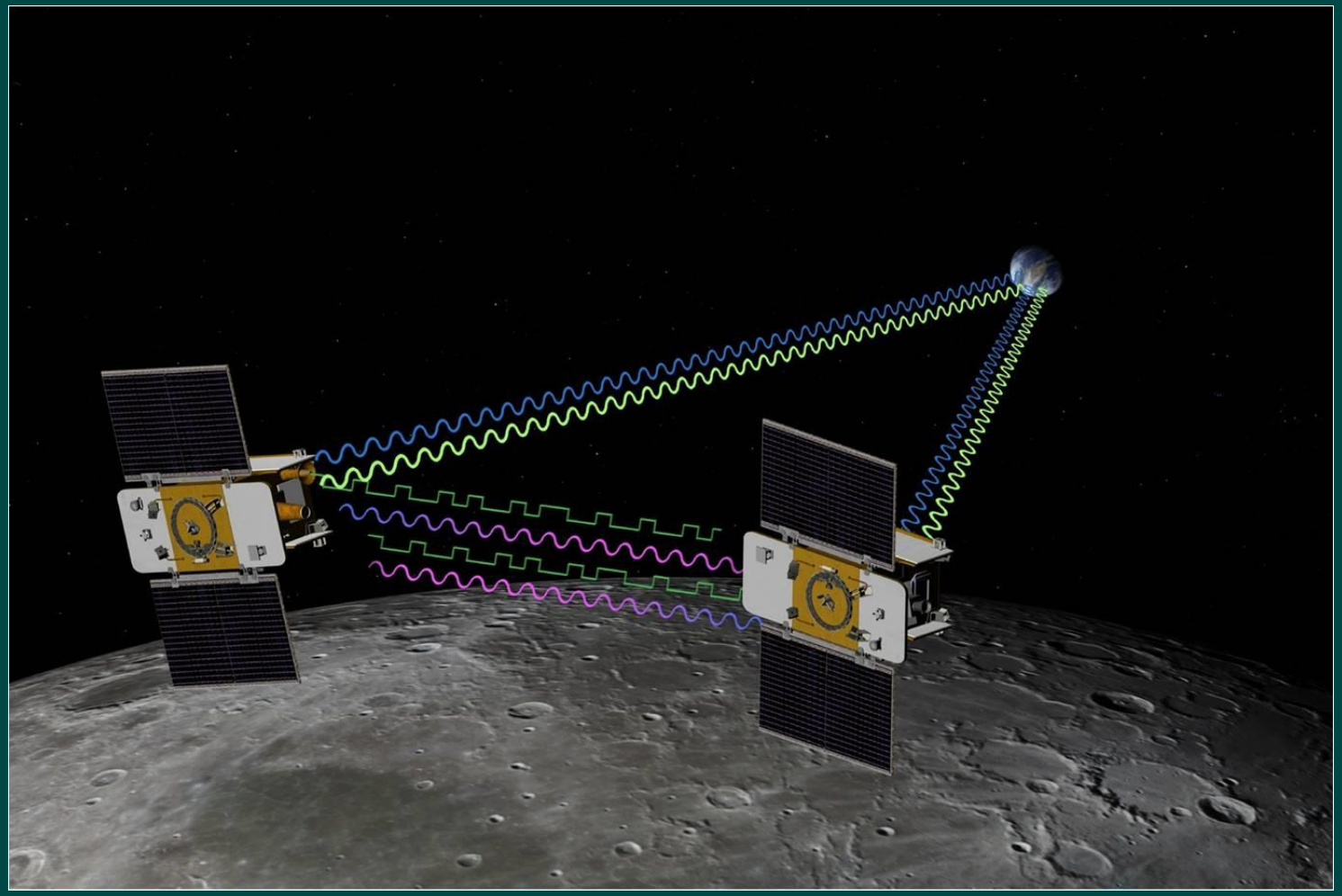

Mars Science Laboratory Mission - NASA launch

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Mars Science Laboratory Mission - NASA launched 26th Nov 2011 – heading for the inside of the Gale Crater - Curiosity

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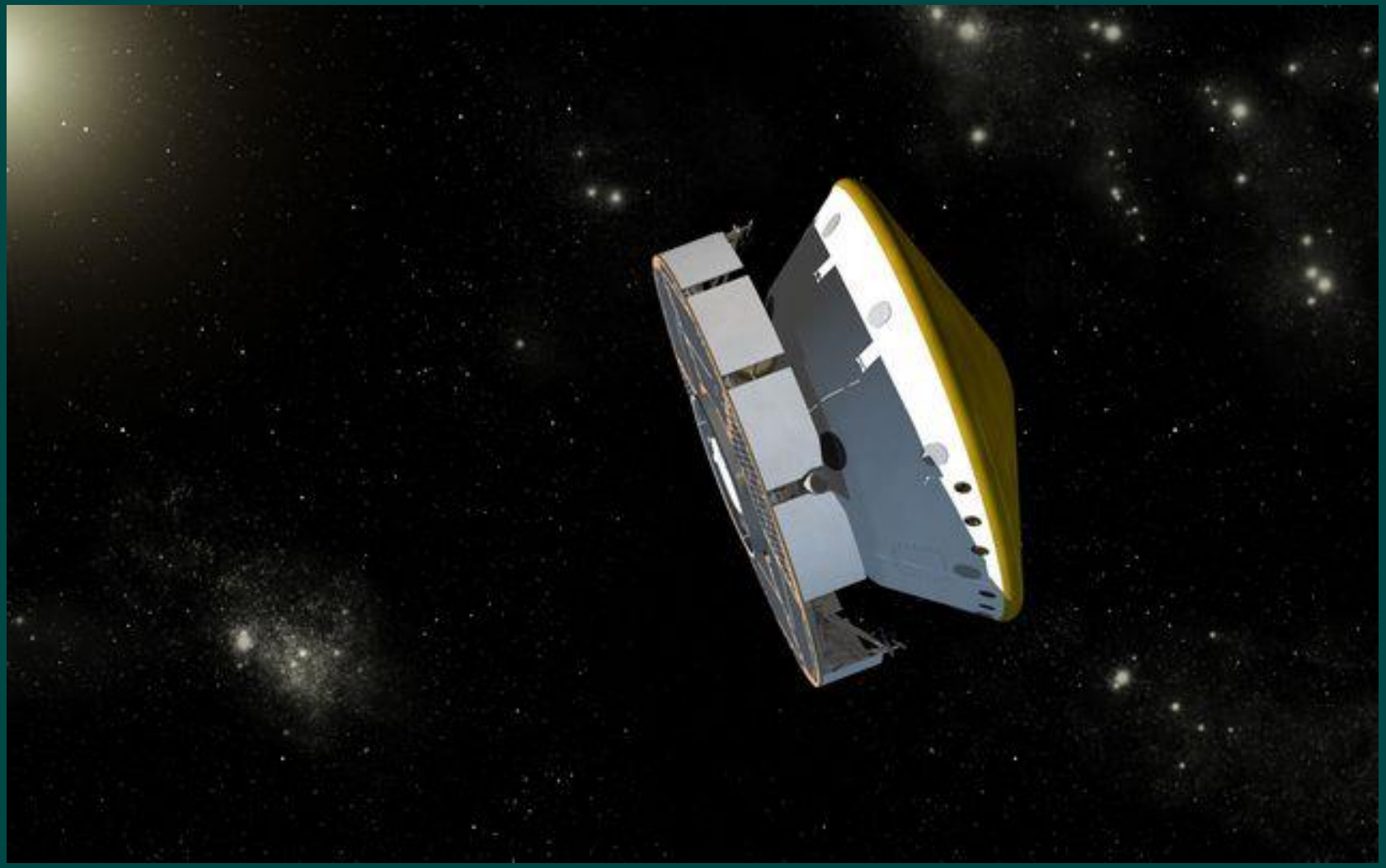

Mars Rover & Curiosity

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- https://www.youtube.com/watch?v=XRCIzZHpFtY

- Curiosity
- https://www.youtube.com/watch?v=FZYnIsLNz3c

NASA's Curiosity Rover in Profile

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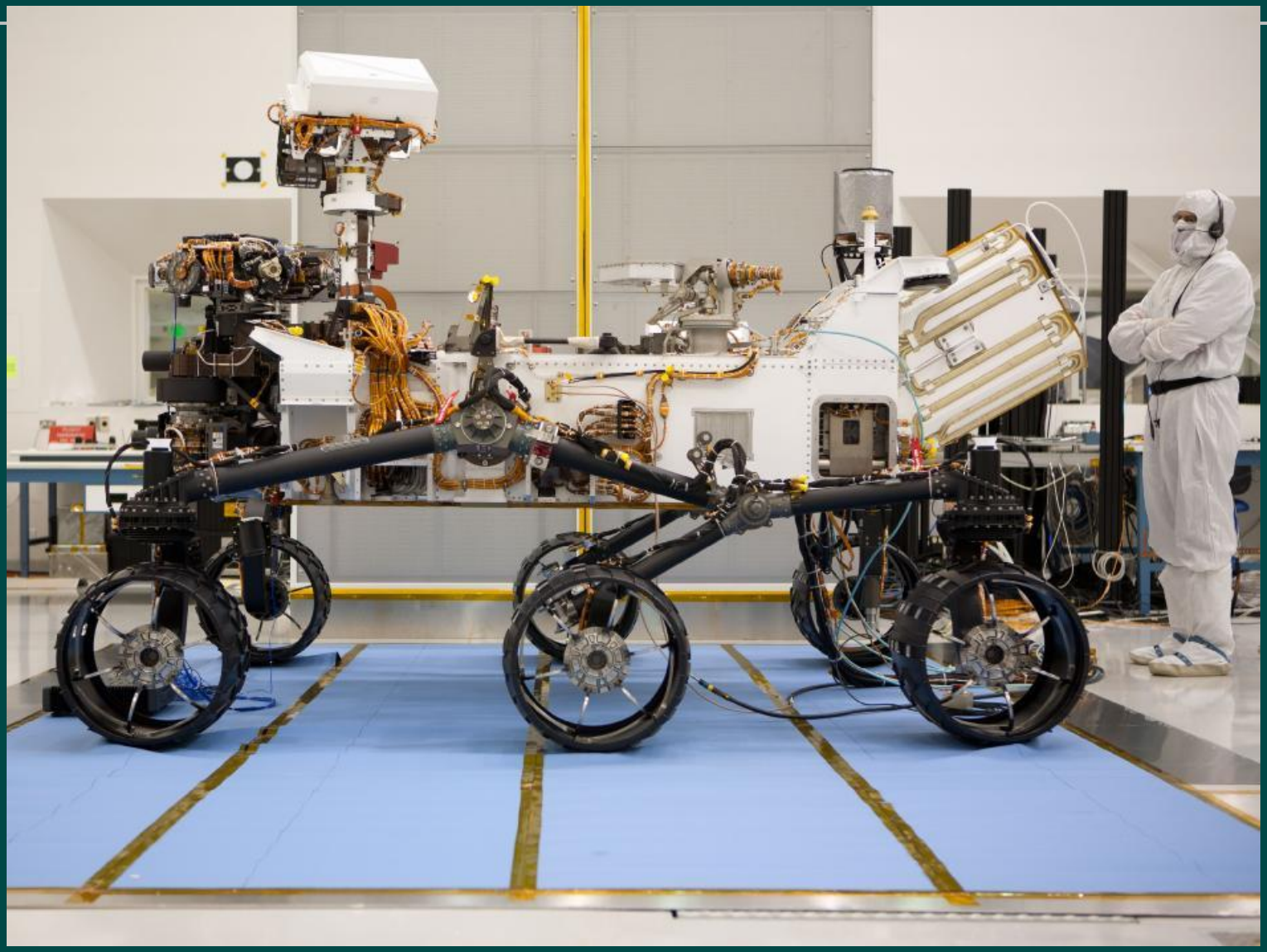

NASA's Curiosity Rover on Mars

http://www.nasa.gov/mission_pages/mars/main/index.html

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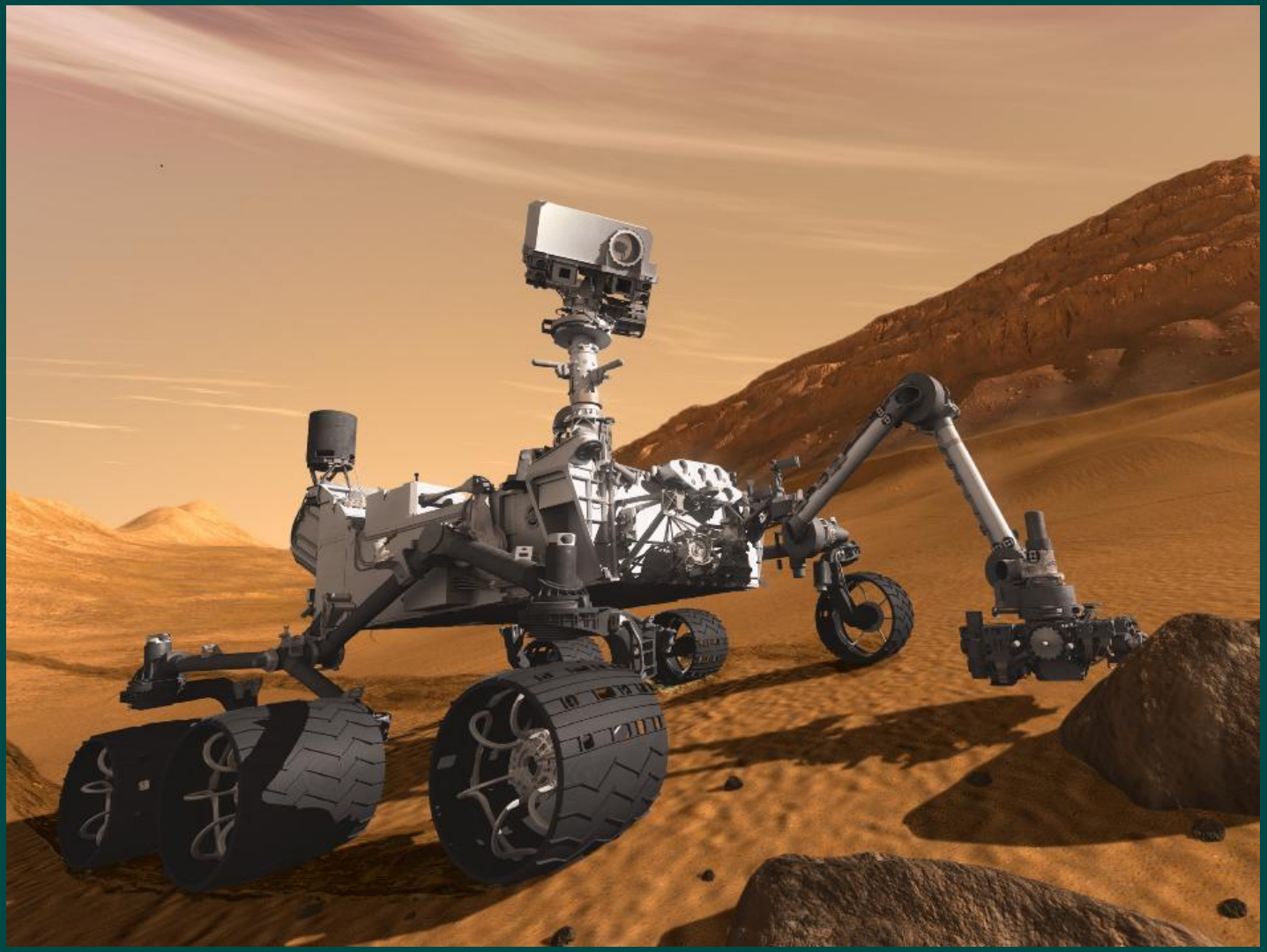
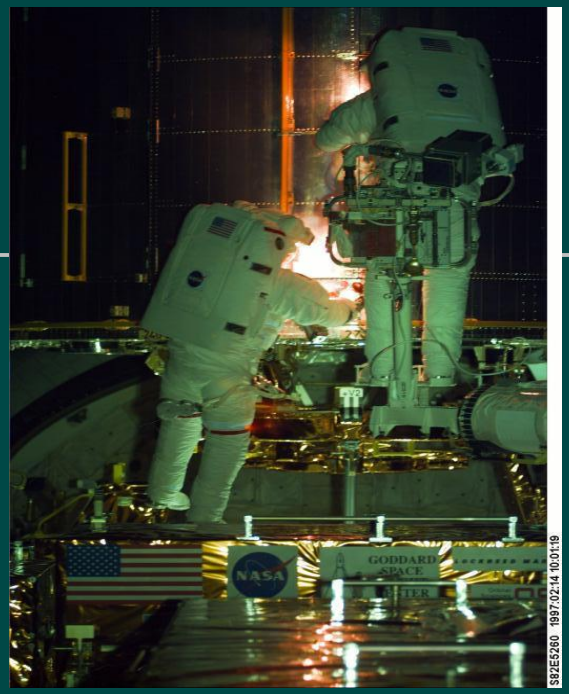
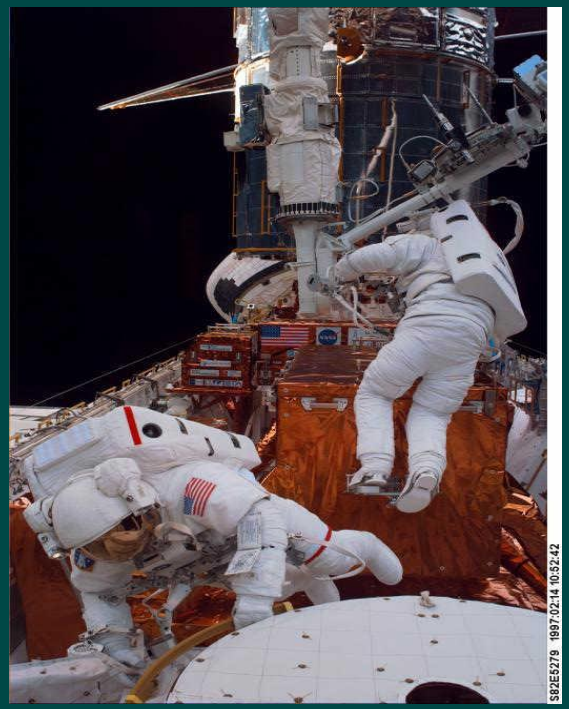
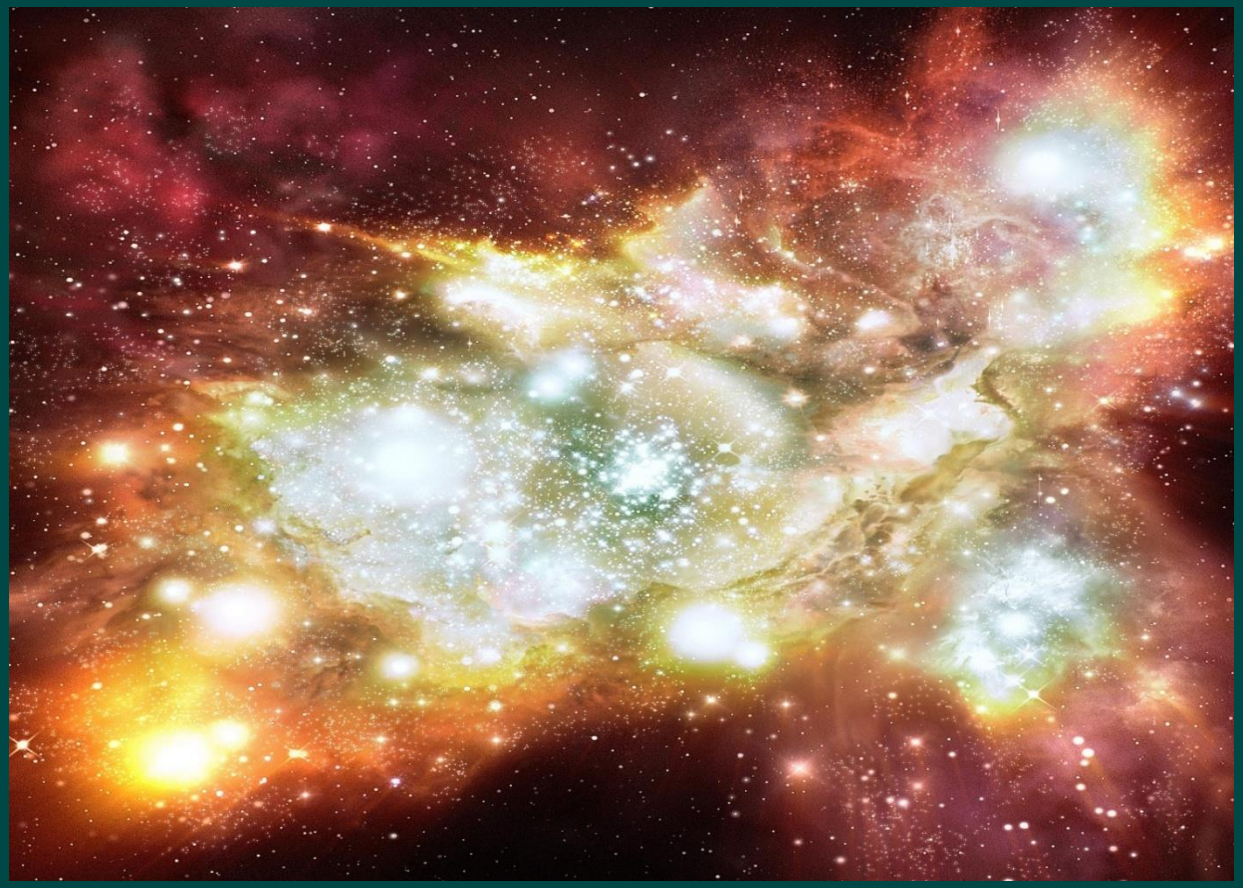


Hubble Space Telescope







Galaxy GN-108036, dating back to 750 million years after the Big Bang that created our universe.

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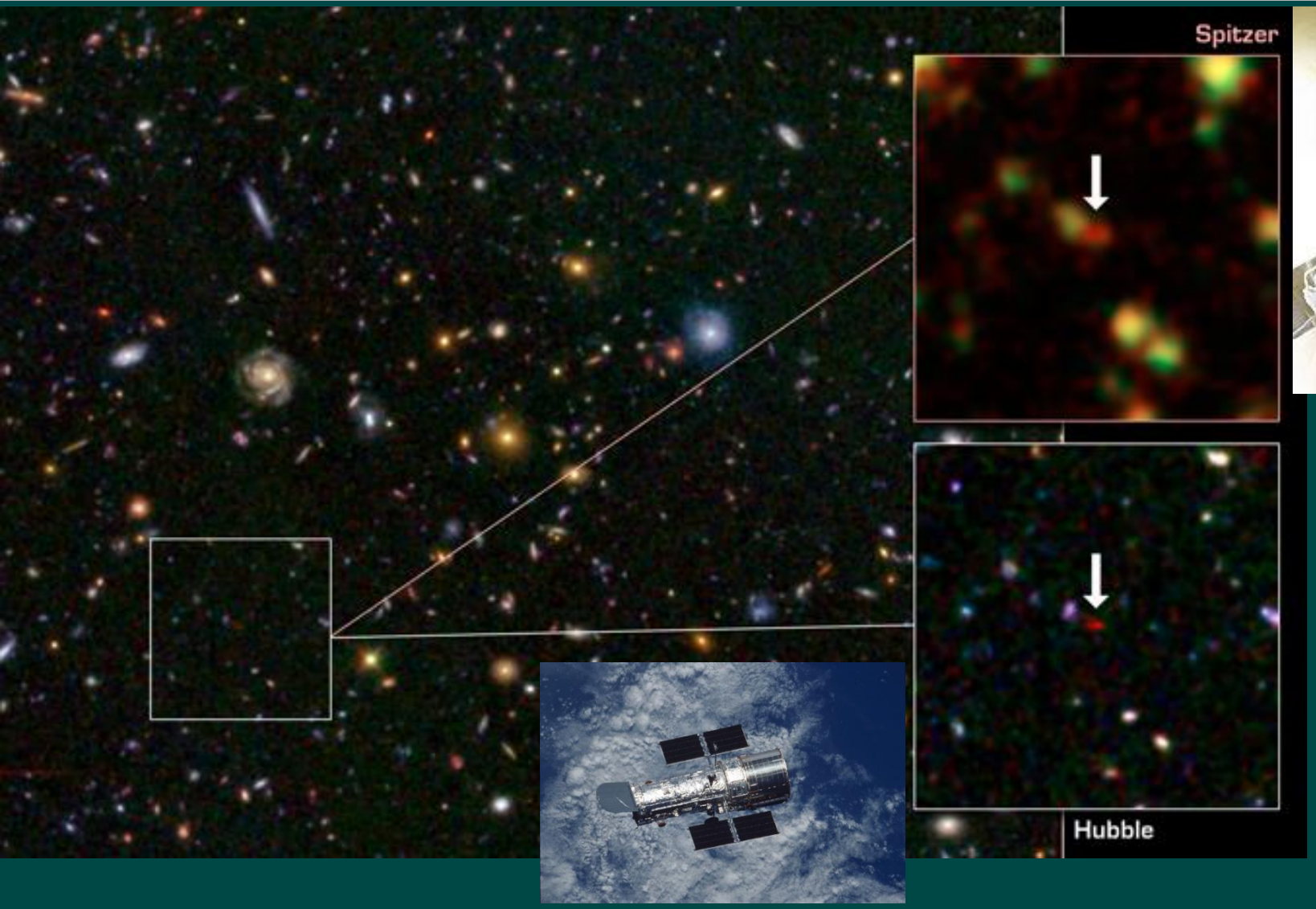

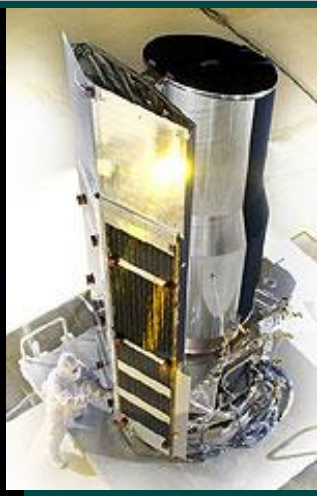


ПРОТОН-М

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http://spaceflightnow.com/proton/is22/launch/

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